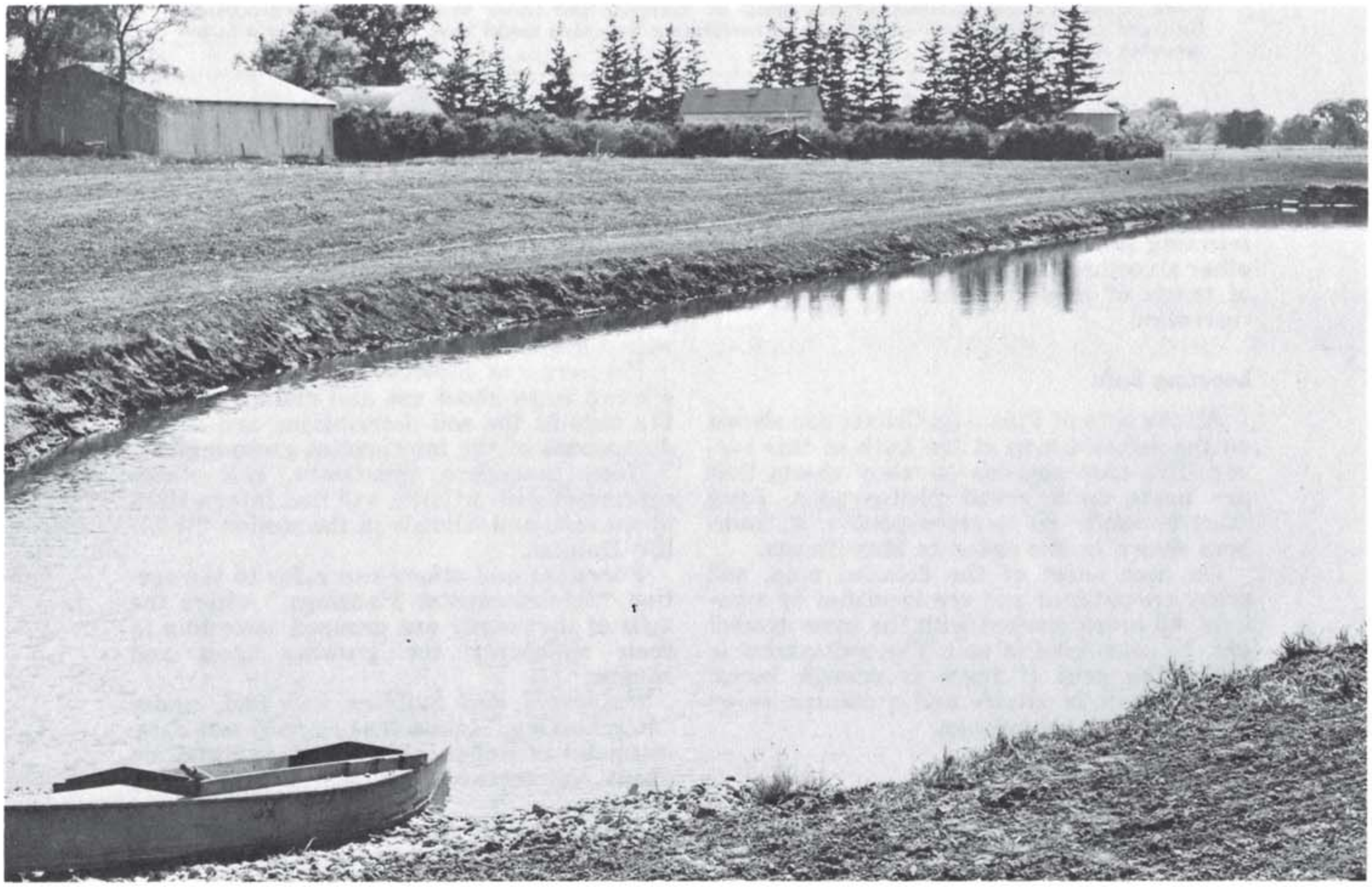
SOIL SURVEY OF

Palo Alto County, Iowa



United States Department of Agriculture
Soil Conservation Service
in cooperation with
Iowa Agriculture and Home Economics Experiment Station
Cooperative Extension Service, Iowa State University
and
Department of Soil Conservation, State of Iowa

This is a publication of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and agencies of the States, usually the Agricultural Experiment Stations. In some surveys, other Federal and local agencies also contribute. The Soil Conservation Service has leadership for the Federal part of the National Cooperative Soil Survey.

Major fieldwork for this soil survey was completed in the period 1962-71. Soil names and descriptions were approved in 1972. Unless otherwise indicated, statements in the publication refer to conditions in the county in 1971. This survey was made cooperatively by the Soil Conservation Service and the Iowa Agriculture and Home Economics Experiment Station, the Cooperative Extension Service, Iowa State University, and the Department of Soil Conservation, State of Iowa. It is part of the technical assistance furnished to the Palo Alto County Soil Conservation Service. Funds appropriated by Palo Alto County and the State of Iowa were used to defray part of the cost of this survey.

HOW TO USE THIS SOIL SURVEY

THIS SOIL SURVEY contains information that can be applied in managing farms; in selecting sites for roads, ponds, buildings, or other structures; and in appraising the value of tracts of land for farming, industry, or recreation.

Locating Soils

All the soils of Palo Alto County are shown on the detailed map at the back of this survey. This map consists of many sheets that are made from aerial photographs. Each sheet is numbered to correspond with numbers shown on the Index to Map Sheets.

On each sheet of the detailed map, soil areas are outlined and are identified by symbols. All areas marked with the same symbol are the same kind of soil. The soil symbol is inside the area if there is enough room; otherwise, it is outside and a pointer shows where the symbol belongs.

Finding and Using Information

The "Guide to Mapping Units" can be used to find information. This guide lists all the soils of the county in numerical order by map symbol and gives the capability classification and environmental planting group of each. It also shows the page where each soil is described and the page for the capability unit to which the soil has been assigned.

Individual colored maps showing the relative suitability or degree of limitation of soils for many specific purposes can be developed by using the soil map and the information in the text. Translucent material can be used as an overlay over the soil map and colored to show soils that have the same limitation or suitability. For example, soils that have a slight limitation for a given use can be colored green, those with a moderate limitation can be colored yellow, and those with a severe limitation can be colored red.

Farmers and those who work with farmers can learn about use and management of the soils in the soil descriptions and in the discussions of the interpretive groupings.

Game managers, sportsmen, and others concerned with wildlife will find information about soils and wildlife in the section "Wildlife Habitat."

Foresters and others can refer to the section "Environmental Plantings," where the soils of the county are grouped according to their suitability for growing trees and shrubs.

Engineers and builders will find, under "Engineering," tables that contain test data, estimates of soil properties, and information about soil features that affect engineering practices.

Scientists and others can read about how the soils were formed and how they are classified in the section "Formation and Classification of Soils."

Students, teachers, and others will find information about soils and their management in various parts of the text.

Newcomers in Palo Alto County may be especially interested in the section "General Soil Map," where broad patterns of soils are described. They may also be interested in the additional information given in the section "Environmental Factors Affecting Soil Use."

Cover: Dugout farm pond in an undrained area of Okoboji silty clay loam. Ponds provide recreation, water for livestock, and fire protection for the farmstead.

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Issued January 1977

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SOIL SURVEY OF PALO ALTO COUNTY, IOWA

BY ROBERT G. JONES, SOIL CONSERVATION SERVICE

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UNITED STATES DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE, IN COOPERATION WITH THE IOWA AGRICULTURE AND HOME ECONOMICS EXPERIMENT STATION, THE COOPERATIVE EXTENSION SERVICE, IOWA STATE UNIVERSITY, AND THE DEPARTMENT OF SOIL CONSERVATION, STATE OF IOWA

PALO ALTO COUNTY is in the northwestern part of Iowa (fig. 1). It has an area of about 561 square miles, or 359,040 acres. Emmetsburg, the county seat, is about 120 airline miles from Des Moines, the State capital.

The county is chiefly agricultural. The principal crops are corn, soybeans, oats, and hay. Soybeans and corn are the most important crops sold, and much of the corn is fed to livestock. Beef cattle and hogs are the principal sources of income on some farms.

How This Survey Was Made

Soil scientists made this survey to learn what kinds of soil are in Palo Alto County, where they are located, and how they can be used. They went into the county knowing they likely would find many soils they had already seen and perhaps some they had not. As they traveled over the county, they observed steepness, length, and shape of slopes; size of streams; kinds of native plants or crops; kinds of rock; and many facts about the soils. They dug or bored many holes to expose soil profiles. A profile is the sequence of natural layers, or horizons, in a soil; it extends from the surface down to the rock material that has not been changed much by leaching or by roots of plants.

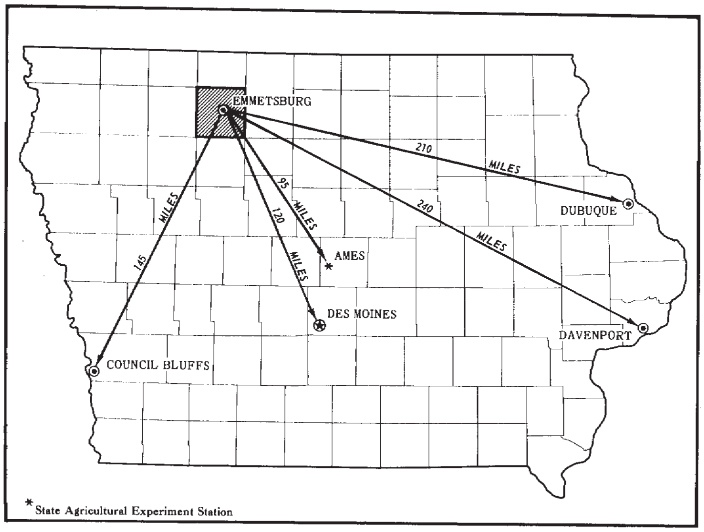

Figure 1.—Location of Palo Alto County in Iowa.

The soil scientists made comparisons among the profiles they studied, and they compared these profiles with those in counties nearby and in places more distant. They classified and named the soils according to uniform procedures. To use this survey efficiently, it is necessary to know the kinds of groupings most used in a local soil classification.

Soils that have profiles almost alike make up a soil series. Except for different textures in the surface layer, all the soils of one series have major horizons that are similar in thickness, arrangement, and other important characteristics. Some soil series are named for a town or other geographic feature near the place where a soil of that series was first observed and mapped. Clarion and Cylinder, for example, are the names of two soil series. All the soils in the United States having the same series name are essentially alike in natural characteristics.

Many soil series contain soils that are alike except for texture of their surface layer. According to this difference in texture, separations called soil types are made. Within a series, all the soils having a surface layer in the same texture belong to one soil type. Okoboji mucky silt loam and Okoboji silty clay loam are two soil types in the Okoboji series. The difference in texture of their surface layers is apparent from their names.

Some soil types vary so much in slope, degree of erosion, number and size of stones, or some other feature affecting their use, that practical suggestions about their management could not be made if they were shown on the soil map as one unit. Such soil types are divided into soil phases (*13*).[1] The name of a soil

[1] Italic numbers in parentheses refer to Literature Cited, page 98.

phase indicates a feature that affects management. For example, Clarion loam, 2 to 5 percent slopes, is one of several phases of Clarion loam, a soil type that ranges from gently sloping to strongly sloping.

After a fairly detailed guide for classifying and naming the soils had been worked out, the soil scientists drew soil boundaries on aerial photographs. They used photos for their base map because the photos show buildings, field borders, trees, and similar details that help in drawing boundaries accurately. The soil map in the back of this survey was prepared from the aerial photographs.

The areas shown on a soil map are called mapping units. On most maps detailed enough to be useful in planning management of farms and fields, a mapping unit is nearly equivalent to a soil type or a phase of a soil type. It is not exactly equivalent, because it is not practical to show on such a map all the small, scattered bits of soil of some other kind that have been seen within an area that is dominantly of a recognized soil phase. For this reason, and because new soils are being recognized, the detailed soil maps of Palo Alto and Clay Counties do not join exactly.

In preparing some detailed maps, the soil scientist has a problem of delineating areas where different kinds of soil are so intricately mixed and so small in size that it is not practical to show them separately on the map. Therefore, he shows this mixture of soils as one mapping unit and calls it a soil complex. Ordinarily, a soil complex is named for the major soils, for example, Colo-Spillville complex.

But only part of a soil survey is done when the soils have been named, described, and delineated on the map and the laboratory data and yield data have been assembled. The mass of detailed information then needs to be organized in such a way that it is readily useful to different groups of readers, among them farmers, managers of woodland, engineers, and home owners. Grouping soils that are similar in suitability for each specified use is the method of organization commonly used in the soil survey.

The soil scientists set up trial groups based on the yield and practice tables and other data. They test these groups by further study and by consultation with farmers, agronomists, engineers, and others; then they adjust the groups according to the results of their studies and consultations. Thus, the groups that are finally evolved reflect up-to-date knowledge of the soils and their behavior under present methods of use and management. Such groupings are the capability classes, subclasses, and units, designed primarily for those interested in producing the short-lived crops and pasture; environmental planting groups, for those who need to manage trees; and the classification used by engineers who build highways or structures to conserve soil and water.

Soil interpretation tables are developed which show the suitability of soil series—type and phase—for different uses. Such interpretation tables are developed for wildlife habitat, engineering measures or structures, and for crops, pasture, and environmental planting groups.

General Soil Map

The general soil map at the back of this survey shows, in color, the soil associations in the survey area. A soil association is a landscape that has a distinctive pattern of soils in defined proportions. It typically consists of one or more major soils and at least one minor soil, and it is named for the major soils. The soils in an association can occur in other associations, but in different patterns. For this reason, the general soil maps of Palo Alto and Clay Counties do not join exactly.

A map showing soil associations is useful to people who want to have a general idea of the soils in a survey area, who want to compare different parts of that area, or who want to locate large tracts that are suitable for a certain kind of land use. Such a map is a useful general guide for broad planning on a watershed, a wooded tract, or a wildlife area or for broad planning of recreational facilities, community developments, and such engineering works as transportation corridors. It is not a suitable map for detailed planning for management of a farm or field or for selecting the exact location of a road or building or other structure, because the soils within an association ordinarily vary in slope, depth, stoniness, drainage, and other characteristics that affect their management.

The soil associations in this survey area are described on the pages that follow.

1. *Canisteo-Nicollet-Webster association*

Nearly level, medium textured and moderately fine textured, poorly drained and somewhat poorly drained soils on uplands

This association is in the eastern part of the county, mainly on nearly level uplands. Prairie Creek, a small stream bordered by a narrow and often indistinct flood plain, flows through the association, but most parts do not have a natural drainage pattern. The many extensive nearly level areas and the shallow depressions are drained by tile.

This association (fig. 2) makes up about 3 percent of the county. It is about 40 percent Canisteo soils, 30 percent Nicollet soils, 15 percent Webster soils, and 15 percent Clarion, Harps, Crippin, and Okoboji soils.

The poorly drained Canisteo and Webster soils have a surface layer of black to very dark gray silty clay loam to clay loam about 16 to 24 inches thick. The subsoil is mainly olive gray silty clay loam, clay loam, or loam. These soils occupy broad flats and swales (fig. 3). They formed in glacial till and glacial till sediments. Canisteo soils are calcareous. Webster soils are noncalcareous in the upper part, but they are typically calcareous below a depth of about 30 inches.

The somewhat poorly drained Nicollet soils have a surface layer of black or very dark brown loam, which grades to a subsoil of dark grayish brown light clay loam. Nicollet soils typically occupy slightly convex areas that rise above the low-lying Canisteo or Webster soils, and slopes are typically 1 to 3 percent.

The well drained Clarion loams are on the higher parts of rises. Crippin soils are in the same position on the landscape as Nicollet soils. Okoboji soils are in very

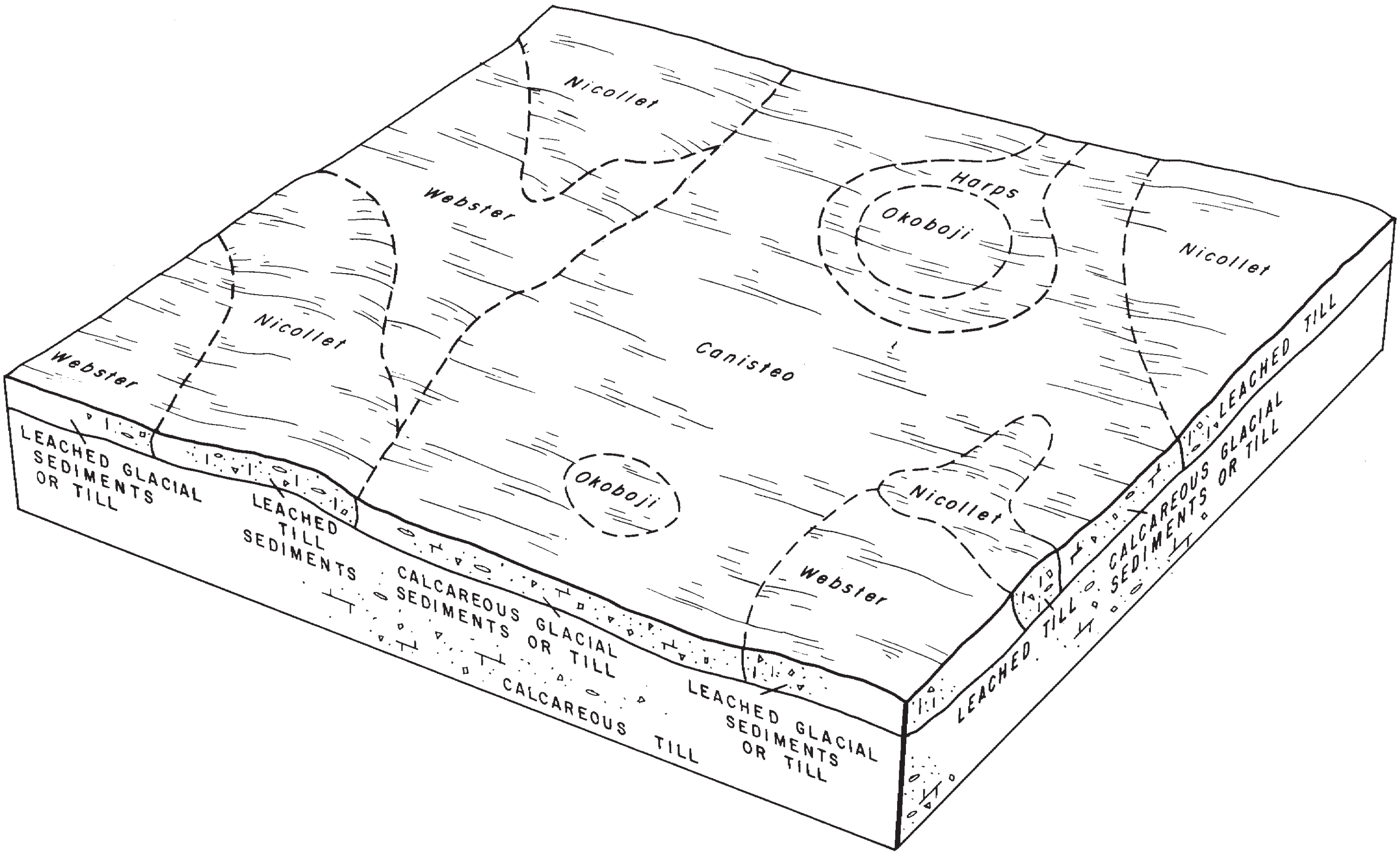

Figure 2.—**Pattern of soils and parent material in the Canisteo-Nicollet-Webster association.**

wet depressions; they are often ponded in spring and after heavy rains. The nearly level, highly calcareous Harps soils are on rims around depressions.

Most of this association is used for crops, and is well suited to row crops. Corn and soybeans are the main crops, but some oats and crops for rotation hay and pasture, including alfalfa and alfalfa-grass mixture, are also grown. Organic-matter content and available water capacity are high. Crops respond well to fertilization.

The main concerns of management are improving drainage and maintaining tilth and fertility. Erosion is a hazard in a few areas of Clarion soils. Low fertility is a concern on Harps soils. Most areas are tile drained, but additional tile is needed in some places.

Cash-grain type farming is more dominant in this association than in other parts of Palo Alto County. Much of the grain is sold for cash, but many farmers raise hogs or beef cattle, and there are a few beef cow-calf herds. All livestock enterprises can be further developed.

Most roads follow section lines. All are hard surfaced or gravelled.

2. *Clarion-Canisteo-Nicollet association*

Gently sloping and nearly level, medium textured and moderately fine textured, well drained to poorly drained soils on uplands

This association is an undulating ground moraine of swales and rises that differ from about 5 to 10 feet in elevation. It is mostly nearly level and gently sloping. Slopes are steeper in a few places around the many scattered potholes and along the drainageways. Slopes are generally short. Pilot Creek and Beaver Creek flow through this association and make good outlets for tile drains. They have narrow and indistinct flood plains.

This association (fig. 4) makes up about 10 percent of the county. It is about 35 percent Clarion soils, 25 percent Canisteo soils, 20 percent Nicollet soils, and 20 percent Storden, Okoboji, Harps, Webster, Colo, Biscay, and Cylinder soils.

The well drained Clarion soils have a black or very dark brown surface layer and a brown to yellowish brown subsoil. They are mostly loam. These soils formed in glacial till. Clarion soils are on the higher parts of the landscape and on low, short-sloped, irregular convex ridges that rise above areas of Nicollet or Canisteo soils. Slopes are typically 3 to 5 percent, but some are steeper.

The poorly drained Canisteo soils have a surface layer of black to very dark gray silty clay loam to clay loam about 16 to 24 inches thick. The subsoil is mainly olive gray silty clay loam, clay loam, or loam. Canisteo soils, which formed in glacial till and glacial till sediments and are calcareous, are on broad flats and in swales.

***Figure 3.*—Corn and soybeans on nearly level Canisteo soil in Canisteo-Nicollet-Webster association. Light-colored patch in background is Harps soil, a minor soil in the association.**

The somewhat poorly drained Nicollet soils have a surface layer of black or very dark brown loam. The subsoil is dark grayish brown light clay loam. In this association, Nicollet soils are typically on slight rises on the broad flats of Canisteo soils. Some are between the well-drained Clarion soils and the poorly drained soils that are lower on the landscape. Slopes are 1 to 3 percent.

Storden soils are moderately sloping and have short slopes. Okoboji soils are in depressions, and some of the larger areas have a surface layer of mucky silt loam. These areas are often ponded in spring and after heavy rains. Harps loam, which is a highly calcareous soil, is on the nearly level rims surrounding the depressions. Webster soils occupy broad flats and swales. Colo soils are on the present or former flood plains of Pilot and Beaver Creeks. Biscay and Cylinder soils formed in glacial outwash along the two creeks.

Most of this association is used for crops. It is well suited to row crops. Corn and soybeans are the main crops. Some oats and crops for rotation hay and pasture, for example, alfalfa and alfalfa-grass mixtures, are generally grown. A few small areas, mostly around farmsteads, are in permanent pasture.

The Clarion soil is moderate in organic-matter content, and the rest are high. Available water capacity is high in all the soils. Crops respond well to fertilization.

Erosion is a hazard on sloping soils. The irregular pattern of slopes makes contouring and terracing somewhat difficult in some places. Drainage is frequently needed on nearly level, poorly drained soils and the very poorly drained soils in depressions. Most areas are tile drained. Maintaining and improving fertility and tilth are important. Particular attention to fertility is necessary on Harps soils.

Cash-grain type farming is dominant in this association. Much of the grain is sold for cash, but many farmers raise hogs or beef cattle, and there are a few beef cow-calf herds. All livestock enterprises can be further developed.

Most roads follow section lines. All are hard surfaced or gravelled.

3. *Clarion-Nicollet-Canisteo association*

Moderately sloping to nearly level, medium textured and moderately fine textured, well drained to poorly drained soils on uplands

This association is an undulating ground moraine of swales and rises that differ from about 5 to 20 feet in elevation. It is dominantly nearly level to moderately sloping. Slopes are steeper in a few places around the many scattered potholes. Cylinder Creek, Beaver Creek,

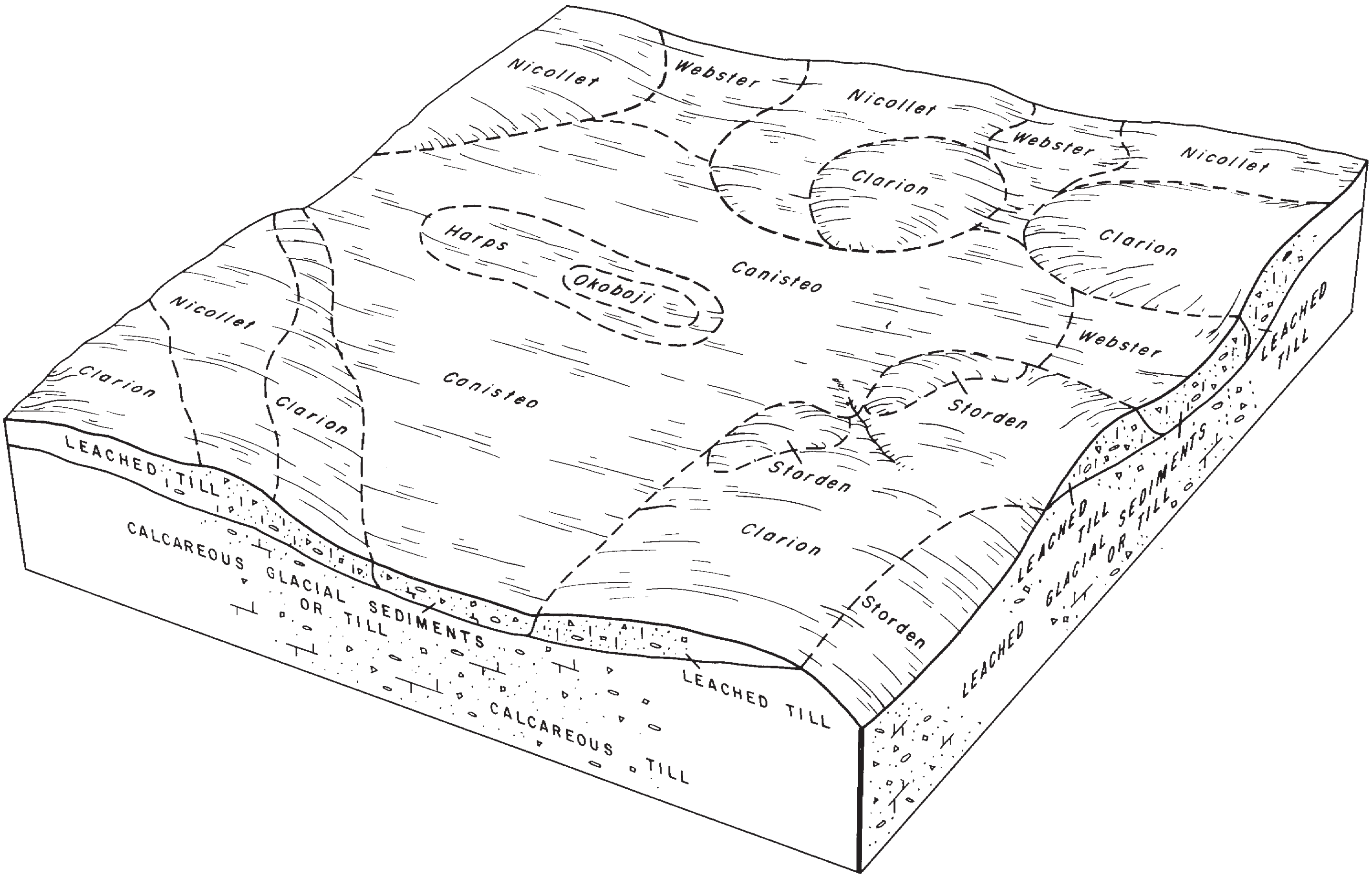

Figure 4.—**Pattern of soils and parent material in Clarion-Canisteo-Nicollet association.**

Prairie Creek, and Dry Ditch flow through this association. Their channels have been straightened and deepened in places and make good outlets for tile drains. All but Cylinder Creek have narrow, indistinct flood plains.

This association makes up about 30 percent of the county. It is about 35 percent Clarion soils, 20 percent Nicollet soils, 15 percent Canisteo soils, 10 percent Webster soils, and about 20 percent Storden, Okoboji, Harps, Waldorf, Crippin, Colo, Biscay, and Cylinder soils.

The well drained Clarion soils have a surface layer of black or very dark brown loam. The subsoil is brown to yellowish brown loam. These soils formed in glacial till. They are on higher parts of the uplands and on low, short-sloped, irregular convex ridges that rise above areas of Nicollet soils. Slopes are dominantly 2 to 9 percent, but some are steeper.

The somewhat poorly drained Nicollet soils have a surface layer of black or very dark brown loam. The subsoil is very dark grayish brown light clay loam. In this association, Nicollet soils are typically on slight rises on the broad flats of Canisteo or Webster soils and between the well drained Clarion soils and the poorly drained Canisteo or Webster soils. Slopes are 1 to 3 percent.

The poorly drained Canisteo and Webster soils have a surface layer of black to very dark gray silty clay loam to clay loam about 16 to 24 inches thick. The subsoil is mainly olive gray silty clay loam, clay loam, or loam. Canisteo soils, which are calcareous, are on broad flats and in swales and generally surround areas of depressional soils. A drainage network has not developed. Webster soils, which formed in glacial till and glacial till sediments and are noncalcareous, are mostly in concave swales or on higher parts of broad flats that have a drainage network partly developed.

Storden soils have mostly short, moderate to steep slopes. Okoboji soils are in depressions and are often ponded in spring and after heavy rains. In some of the larger areas the surface layer is mucky silt loam. Harps loam, a highly calcareous soil, is on the nearly level rims surrounding the Okoboji soils in depressions. Colo soils are on the present or former flood plains of the creeks. Waldorf soils, which are fine textured, are mostly in broad concave swales that are generally slightly higher in elevation than the Webster and Canisteo soils. Crippin soils are on low rises adjacent to Canisteo soils. Biscay and Cylinder soils formed in glacial outwash adjacent to the creeks and in a few isolated areas in the uplands.

Most of this association is used for crops and is well suited to row crops. The moderate slopes are only moderately suited. Corn and soybeans are the main

crops. Some oats are grown, and alfalfa or alfalfa-grass mixtures are grown for hay and rotation pasture. A few areas, mostly along the creeks and around farmsteads, are in permanent pasture.

The Clarion soil is moderate in organic-matter content, and the rest are high. Available water capacity is high in all the soils. Crops respond well to fertilization.

The sloping soils need protection from erosion. The irregular pattern of slopes make contour tillage and terracing somewhat difficult in some places. The nearly level, poorly drained and very poorly drained soils and the very poorly drained soils in depressions are generally tile drained. Many areas need improved drainage. Maintaining fertility and tilth are important. Low fertility is a concern on Harps soils.

Cash-grain type farming is dominant in this association. Much of the grain is sold for cash, but many farmers raise hogs or beef cattle, and there are a few beef cow-calf herds. All livestock enterprises can be further developed.

Most roads follow section lines. Almost all roads are hard surfaced or gravelled.

4. Clarion-Nicollet association

Strongly sloping to nearly level, medium textured, well drained to somewhat poorly drained soils on uplands

This association is an undulating to gently rolling ground moraine of swales and ridges that differ from 5 to 30 feet in elevation. It is mostly nearly level to strongly sloping, but is steeper around the many scattered potholes and along the drainageways. Most slopes are short. Lizard Creek, Pilot Creek, Beaver Creek, Prairie Creek, Silver Creek, Jack Creek, and Pickerel Run flow through parts of this association. In most places they have narrow, indistinct flood plains.

This association occurs as one large area west of the West Fork Des Moines River and eight smaller areas in other parts of the county. It makes up about 30 percent of the county. It is about 45 percent Clarion soils (fig. 5), 20 percent Nicollet soils, and about 35 percent Storden, Canisteo, Webster, Blue Earth, Okoboji, Harps, Spillville, Rolfe, Waldorf, Colo, Biscay, Cylinder, Wadena, and Salida soils.

The well drained Clarion soils have a surface layer of black or very dark brown loam and a subsoil of brown to yellowish brown loam. These soils formed in glacial till. In this association, they are on the high parts of the uplands and on low, short-sloped, irregular ridges that rise above areas of Nicollet soils. Slopes are typically about 2 to 14 percent, but in a few places they are steeper.

The somewhat poorly drained Nicollet soils have a surface layer of black or very dark brown loam. The

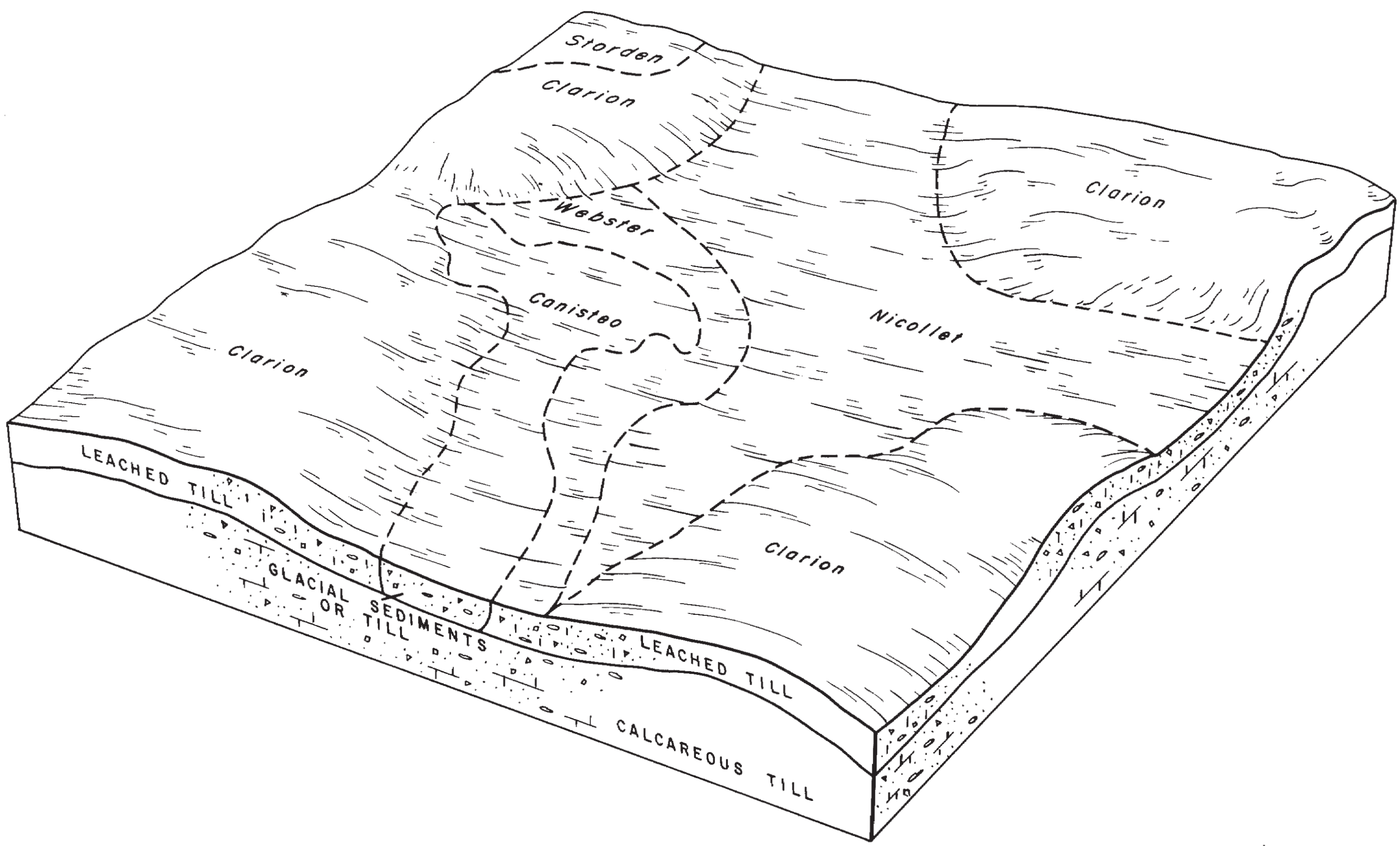

Figure 5.—**Pattern of soils and parent material in Clarion-Nicollet association.**

subsoil is very dark grayish brown light clay loam. In this association, Nicollet soils are typically between the well drained Clarion soils and the poorly drained soils of the upland plains and in a very few places on slightly convex areas that rise above the low-lying plain. Slopes are 1 to 3 percent.

Storden soils, which are somewhat excessively drained, are associated with the Clarion soils. Canisteo soils, which are poorly drained calcareous soils, are on moderately wide flats that have indistinct drainage networks and usually contain areas of depressional soils within their borders. Webster soils are on concave swales that have a drainage network partly developed. Okoboji and Rolfe soils are in saucerlike depressions. Blue Earth soils are in drained lakebeds of former shallow lakes and in large depressional areas. Harps soils, which are highly calcareous, typically surround areas of depressional soils. Spillville soils are on foot slopes below the Storden and Clarion soils.

Most of this association is used for crops, but more is in pasture than in associations 1, 2, and 3. It is mostly well suited or moderately suited to row crops, but in some areas is better suited to hay or pasture. Corn and soybeans are the main crops. Some oats are grown, and crops for rotation hay and pasture, for example, alfalfa and alfalfa-grass mixtures, are grown. A few areas that border streams are wooded.

Most of the soils are moderate or high in organic-matter content and high in available water capacity. Crops commonly grown in the county respond well to fertilization.

The main management needs are controlling erosion on the sloping soils and improving drainage on the wet soils, especially on the depressional soils. The irregular pattern of slopes makes erosion control by contour tillage and terraces somewhat difficult in some places. Maintaining fertility and tilth are important. Low fertility is a concern in some of the minor soils.

General farming is practiced on this association. Much of the grain is sold for cash. The most important livestock enterprise is raising hogs and beef cattle. Beef cow-calf herds are fairly common. There are also a few dairy herds and a few flocks of sheep.

Roads are mainly on section lines. They are hard surfaced or gravelled.

5. Clarion-Storden-Nicollet-Canisteo association

Moderately sloping to moderately steep, medium textured and moderately fine textured, somewhat excessively drained to poorly drained soils on uplands

This association is on the Altamont moraine (*8*), a gently rolling to hilly ground moraine of ridges and swales that differ from about 5 to 45 feet in elevation. The association borders Silver Lake. It is typically moderately sloping to moderately steep, but ranges from nearly level to very steep. The steeper slopes are around the many potholes and large depressions and drainageways. Lost Island, Virgin Lake, Blue Wing Marsh, and several smaller, unnamed marshes, sloughs, and closed depressions are within this association. An old lakebed just south of Ruthven, formerly known as Elbow Lake, has been drained and is now farmed.

This association makes up about 13 percent of the county. It is about 50 percent Clarion soils (fig. 6), 10 percent Storden soils, 10 percent Nicollet soils, 10 percent Canisteo soils, and 20 percent Webster, Okoboji, Rolfe, Harps, Blue Earth, Wadena, and Salida soils.

The well drained Clarion soils have a surface layer of black or very dark brown loam. The subsoil is brown to yellowish brown loam. These soils formed in glacial till. In this association, they are on the high parts of the uplands. Slopes are typically 5 to 14 percent, but in areas near Storden soils they are commonly 14 to 18 percent.

The somewhat excessively drained Storden soils have a thin surface layer of very dark brown or very dark gray loam. The substratum is yellowish brown loam. Slopes are typically 9 to 25 percent, but a few are steeper and some are less steep.

The somewhat poorly drained Nicollet soils have a surface layer of black or very dark brown loam. The subsoil is very dark grayish brown light clay loam. The Nicollet soils in this association are typically between the well drained Clarion soils and the poorly drained soils. Slopes are 1 to 3 percent.

The poorly drained Canisteo soils have a surface layer of black to very dark gray clay loam or silty clay loam about 16 to 24 inches thick. The subsoil is mainly olive gray silty clay loam, clay loam, or loam. Canisteo soils, which formed in glacial till and glacial till sediments and are calcareous, are generally associated with depressional soils and narrow flats. A drainage network has not developed on these soils.

Webster soils, which are noncalcareous, are in concave swales where a partial drainage network has formed. Okoboji soils are in depressions and are commonly surrounded by the highly calcareous Harps soils. Rolfe soils also are in depressions. Blue Earth soils are in small shallow glacial lake basins and large depressions that have been drained. Wadena and Salida soils are on glacial outwash in the uplands.

This association is used for crops and pasture. In many areas it is either too wet or too steep for row crops. In other areas it ranges from well suited to poorly suited. Corn and soybeans are the main crops. Oats and crops for rotation hay and pasture, for example, alfalfa and alfalfa-grass mixtures, are commonly grown. A larger percentage of this association is in pasture, as compared with other soil associations.

The Storden soil is low in organic-matter content, the Clarion is moderate, and the rest are high. Available water capacity is high in all of the soils, but the Storden soils seldom reach their capacity because water readily runs off.

All but some of the steeper Storden soils have a high potential for all cultivated crops commonly grown in the county. Growing soybeans on some of the steeper soils, however, increases the hazard of erosion and should be avoided. Crops generally respond well to additions of fertilizer.

The many depressions, marshes, and lakes in this association provide habitat for waterfowl, muskrats, beaver, upland game animals, and birds.

The need for erosion control is greater on this association than on others in the county. Improved drain-

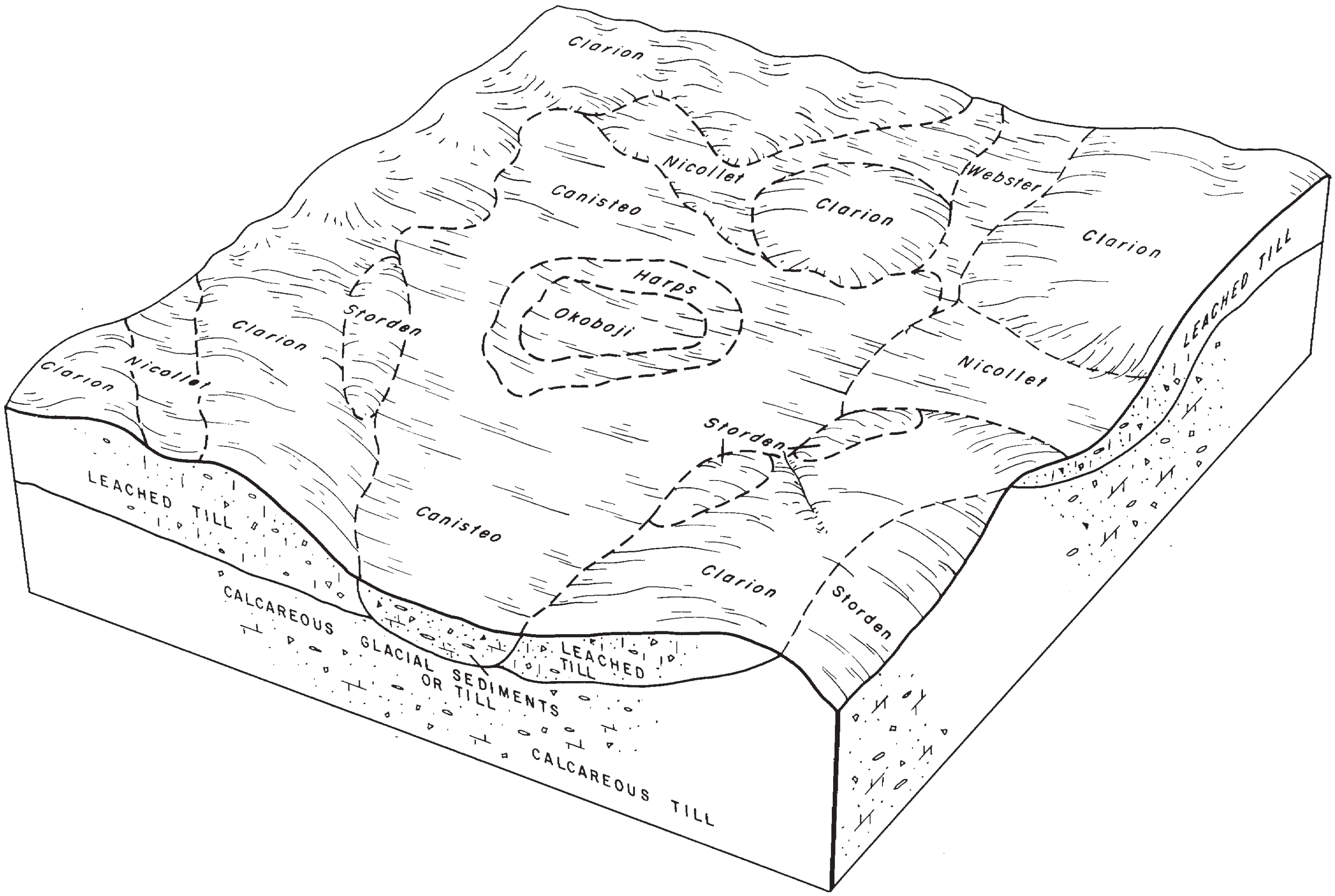

Figure 6.—**Pattern of soils and parent material in Clarion-Storden-Nicollet-Canisteo association.**

age is needed in many areas. Maintaining and improving fertility and tilth are also important. Pasture renovation and reseeding should also be considered.

General farming is practiced on this association. Beef cow and calf herds are common. Most farmers raise hogs, and many fatten beef cattle. There is some dairying. There are also a few sheep flocks. Much of the grain is fed to livestock, but considerable grain is sold for cash. There is potential for further development of the livestock enterprises.

Most roads follow section lines, but some deviate to avoid marshes, lakes, and depressions. Most are hard surfaced or gravelled. Fields are smaller and more irregular in shape than on the other soil associations.

6. *Storden-Clarion-Salida association*

Nearly level to moderately steep, medium textured and moderately coarse textured, well drained to excessively drained soils on uplands and outwash plains

This association is a nearly level to hilly moraine of soils formed in glacial till and outwash. Many areas are characterized by steep slopes and gravelly knobs. Other areas have gently undulating slopes and low knolls of mixed soils formed in till and outwash.

This association occurs as nine small areas in the county, most of which are adjacent to small streams, lakes, marshes, or large depressions. It (fig. 7) makes up about 2 percent of the county. It is about 25 percent Storden soils, 25 percent Clarion soils, 15 percent Salida soils, 15 percent Estherville soils, and about 20 percent Wadena soils, which are loamy over sand and gravel, and Dickman soils, which are sandy loam to sand throughout.

The somewhat excessively drained Storden soils have a thin surface layer of very dark brown or very dark gray loam. The substratum is yellowish brown loam. These soils formed in glacial till. Slopes are typically 9 to 18 percent.

The well drained Clarion soils have a surface layer of black or very dark brown loam and a subsoil of brown to yellowish brown loam. These soils formed in glacial till. Slopes are typically 2 to 9 percent.

The excessively drained Salida soils have a surface layer of very dark brown gravelly sandy loam about 7 inches thick. The subsoil is only about 6 inches thick. It is mixed very dark brown and dark brown gravelly loamy sand that is alkaline. The substratum is loose, calcareous sand and gravel. Salida soils are typically on

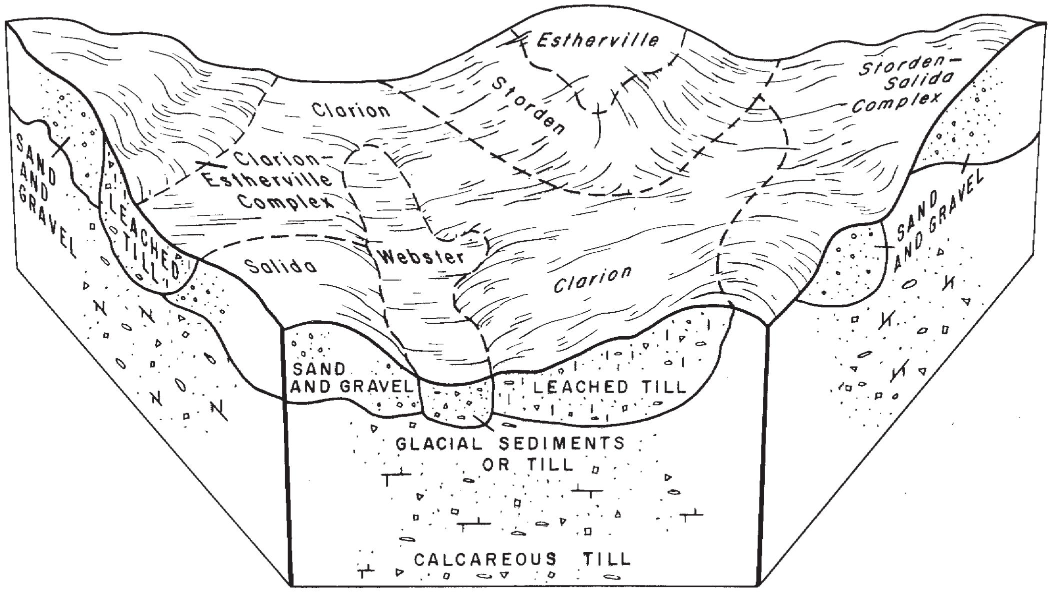

Figure 7.—**Pattern of soils and parent material in Storden-Clarion-Salida association.**

the higher ridges and knobs associated with Storden soils. Slopes are typically 9 to 18 percent, but in some areas are only 2 to 9 percent.

The excessively drained Estherville soils have a surface layer of black to very dark grayish brown loam about 10 inches thick. The subsoil is dark brown sandy loam. The substratum, beginning at a depth between 17 and 24 inches, is calcareous sand and gravel. The Estherville soils in this association are closely associated with the Clarion soils. Slopes are typically 2 to 9 percent.

This association is used for crops and pasture. It ranges from well suited to poorly suited to row crops. Much of this association is better suited to hay and pasture crops. The steeper areas are generally in permanent pasture. Other areas are used for row crops, principally corn (fig. 8) and soybeans. Oats and crops for rotation hay and pasture, for example, alfalfa and alfalfa-grass mixtures, are commonly grown.

These soils range from very low to moderate in organic-matter content. Available water capacity ranges from very low to high.

Soil blowing and water erosion control are needed on this association. Also, Salida and Estherville soils are droughty and conserving moisture is needed. Maintaining the level of organic matter and the tilth are needed on all these soils.

Only a few farms are totally within this association. Areas that extend into fields of better soils are often used for row crops. The potential of these soils can be increased by pasture renovation, including fertilization and planting better yielding grasses and legumes. Management is needed to maintain productivity.

7. *Spillville-Colo association*

Nearly level, moderately well drained to poorly drained, medium textured and moderately fine textured soils on bottom land

This association is along the major streams, mainly the West Fork Des Moines River and Cylinder Creek. Areas are generally about one-half mile wide and closely parallel the channel. Many are cut by old meandering stream channels. The soils formed in alluvium and are susceptible to flooding.

This association (fig. 9) makes up about 8 percent of the county. It is about 35 percent Spillville soils; 35 percent Colo soils; and 30 percent Wabash silty clay, which formed in alluvium, and Biscay, Mayer, Cylinder, and Talcot soils, all of which formed in alluvium that overlies outwash.

The moderately well drained and somewhat poorly drained Spillville soils are black and very dark brown to a depth of about 40 inches. They are typically loam. They are generally adjacent to the channel.

The poorly drained Colo soils are black to a depth of about 40 inches or more. They are dominantly silty clay loam. They are generally farther from the stream than other soils in the association.

This association is used for row crops (fig. 10). It is well suited to row crops, but flooding is a hazard and sometimes delays planting. The flooding, however, usually occurs early enough in spring or is of short duration so that crops can be grown. Corn and soybeans are the main row crops. The soils are high in organic-matter content and have high available water capacity.

Management needs are mainly flood protection and drainage improvement. Flood protection is difficult in most areas, but drainage can be improved in many places. Installing tile drains is usually beneficial on Colo soils. In places, however, suitable outlets are not available.

Few farms are wholly within this association; most farms also include some upland soils. In many places roads are along the edge of this association. They cross the association where bridges have been constructed across major streams.

Figure 8.—**Corn on Clarion and Estherville soils in Storden-Clarion-Salida association. Light-colored patch in center is Estherville soil.**

8. *Estherville-Hanska-Linder association*

Nearly level, excessively drained to poorly drained, moderately coarse textured and medium textured soils on stream benches and outwash plains

Most of this association is along the West Fork Des Moines River and Cylinder Creek. Almost all of the association is nearly level. Where it joins the uplands it is gently sloping to moderately sloping. The soils formed in outwash on stream benches and outwash plains from melting glaciers. Some of the low stream benches are susceptible to flooding.

This association (fig. 11) makes up about 4 percent of the county. It is about 35 percent Estherville soils, 20 percent Hanska soils, 15 percent Linder soils, and about 30 percent Biscay, Cylinder, Wadena, Flagler, Mayer, and Talcot soils.

The excessively drained Estherville soils have a surface layer of dark brown loam or sandy loam about 11 inches thick. The subsoil is dark brown and dark grayish brown sandy loam, loamy sand, or gravelly sand. Calcareous sand and gravel is at a depth of about 40 inches. These soils are on both low and high stream benches, mostly along the West Fork Des Moines River.

The poorly drained Hanska soils have a surface layer of black loam about 17 inches thick. The subsoil is grayish sandy loam. Sand and gravel is at a depth of about 12 inches. Hanska soils are typically on low stream benches.

The somewhat poorly drained Linder soils have a surface layer of black to very dark brown loam about 13 inches thick. The subsoil is grayish brown sandy loam. Calcareous sand and gravel is at a depth of about 24 inches. These soils are on stream benches and glacial outwash plains.

Biscay, Mayer, and Talcot soils are poorly drained, Cylinder soils are somewhat poorly drained, Wadena soils are well drained, and Flagler soils are somewhat excessively drained. All are on stream benches and outwash plains. Sand and gravel is at a depth of about 40 inches in Flagler soils.

This association is used for crops and pasture. It ranges from well suited to moderately suited to row crops. Part of the association is better suited to hay and pasture. Corn and soybeans are the main crops. Oats and crops for rotation hay and pasture, for example, alfalfa and alfalfa-grass mixtures, are commonly grown. All the major soils in this association are droughty. Available water capacity is very low to low.

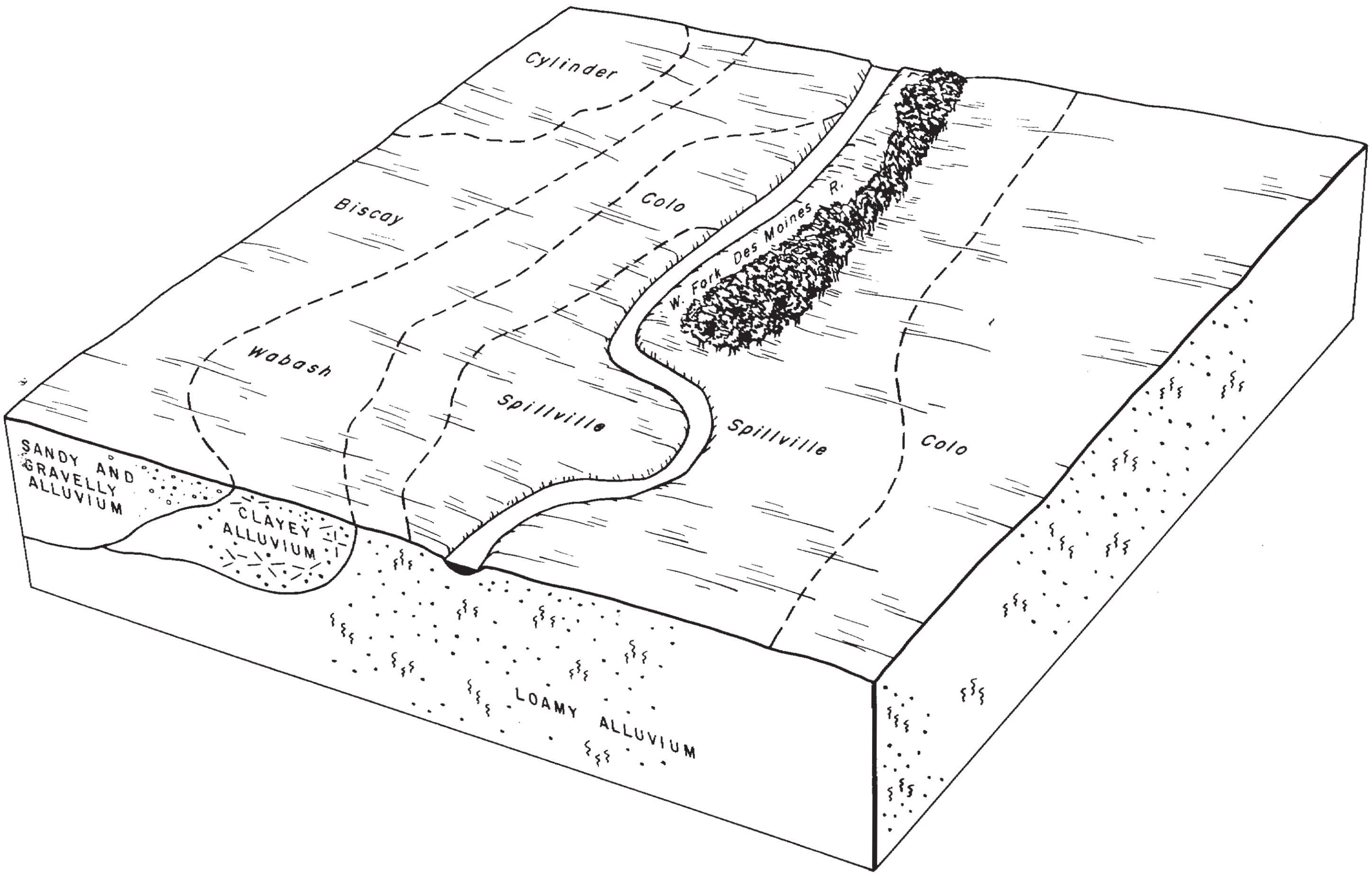

Figure 9.—**Pattern of soils and parent material in Spillville-Colo association.**

All the soils range from low to high in organic-matter content.

The main management problems are preventing soil blowing and conserving moisture. Maintaining tilth and fertility are also important. Some soils need improved drainage.

Few farms are wholly within this association. Most farms also include some upland soils.

Descriptions of the Soils

This section describes the soil series and mapping units in Palo Alto County. Each soil series is described in detail, and then, briefly, each mapping unit in that series is described. Unless it is specifically mentioned otherwise, it is to be assumed that what is stated about the soil series holds true for the mapping units in that series. Thus, to get full information about any one mapping unit, it is necessary to read both the description of the mapping unit and the description of the soil series to which it belongs.

An important part of the description of each soil series is the soil profile, that is, the sequence of layers from the surface downward to rock or other underlying material. Each series contains two descriptions of this profile. The first is brief and in terms familiar to the layman. The second is much more detailed and is for those who need to make thorough and precise studies of soils. The profile described in the series is representative for mapping units in that series. If the profile of a given mapping unit differs from the one described for the series, the differences are stated in describing the mapping unit, or they are differences that are apparent in the name of the mapping unit. Color terms are for moist soil unless otherwise stated.

As mentioned in the section "How This Survey Was Made," not all mapping units are members of a soil series. Marsh, for example, does not belong to a soil series, but it is listed in alphabetic order along with the soil series.

Preceding the name of each mapping unit is a numerical symbol that identifies the mapping unit on the detailed soil map. Listed at the end of each description of a mapping unit is the capability unit and environmental planting group to which the mapping unit has been assigned. The page for the description of each capability unit can be learned by referring to the "Guide to Mapping Units" at the back of this survey.

The acreage and proportionate extent of each mapping unit are shown in table 1. Many of the terms used in describing soils can be found in the Glossary, and

TABLE 1.—*Approximate acreage and proportionate extent of the soils*

Soil	Acres	Percent
Biscay clay loam, deep, 0 to 2 percent slopes	4,775	1.3
Blue Earth mucky silt loam, 0 to 1 percent slopes	1,525	.4
Calco silty clay loam, 0 to 2 percent slopes	1,295	.4
Canisteo silty clay loam, 0 to 2 percent slopes	74,980	20.9
Clarion loam, 2 to 5 percent slopes	57,525	16.0
Clarion loam, 5 to 9 percent slopes	920	.3
Clarion loam, 5 to 9 percent slopes, moderately eroded	23,665	6.7
Clarion loam, 9 to 14 percent slopes, moderately eroded	2,245	.3
Clarion-Estherville complex, 2 to 5 percent slopes	970	.3
Clarion-Estherville complex, 5 to 9 percent slopes, moderately eroded	1,265	.4
Clarion-Storden loams, 2 to 5 percent slopes	700	.2
Colo silty clay loam, 0 to 2 percent slopes	6,075	1.7
Colo silty clay loam, 2 to 4 percent slopes	890	.3
Colo-Spillville complex, 2 to 5 percent slopes	1,635	.5
Crippin loam, 0 to 3 percent slopes	1,505	.4
Cylinder loam, deep, 0 to 2 percent slopes	4,330	1.2
Dickman fine sandy loam, loamy substratum, 0 to 2 percent slopes	535	.1
Dickman fine sandy loam, loamy substratum, 2 to 5 percent slopes	770	.2
Estherville sandy loam, 0 to 2 percent slopes	2,980	.8
Estherville sandy loam, 2 to 5 percent slopes	675	.2
Estherville sandy loam, 5 to 9 percent slopes, moderately eroded	240	.1
Estherville loam, 0 to 2 percent slopes	3,260	.9
Estherville loam, 2 to 5 percent slopes	985	.3
Farrar fine sandy loam, 5 to 9 percent slopes	200	.1
Flagler sandy loam, calcareous subsoil variant, 0 to 2 percent slopes	1,065	.3
Flagler sandy loam, calcareous subsoil variant, 2 to 5 percent slopes	440	.1
Hanska loam, moderately deep, 0 to 2 percent slopes	2,980	.8
Harps loam, 0 to 2 percent slopes	6,930	1.9
Linder loam, 0 to 2 percent slopes	4,835	1.4
Marsh	1,070	.3
Mayer loam, moderately deep, 0 to 2 percent slopes	1,120	.3
Mayer loam, sandy loam subsoil, 0 to 2 percent slopes	845	.2
Nicollet loam, 1 to 3 percent slopes	60,910	17.0
Okoboji silty clay loam, 0 to 1 percent slopes	15,315	4.3
Okoboji mucky silt loam, 0 to 1 percent slopes	2,470	.7
Okoboji silty clay loam, benches, 0 to 1 percent slopes	255	.1
Palms muck, 0 to 1 percent slopes	1,980	.6
Rolfe silt loam, 0 to 1 percent slopes	545	.1
Salida gravelly sandy loam, 4 to 12 percent slopes	805	.3
Spillville loam, 0 to 2 percent slopes	3,155	.9
Spillville loam, 2 to 5 percent slopes	1,545	.4
Spillville loam, channeled, 0 to 2 percent slopes	3,610	1.0
Storden loam, 5 to 9 percent slopes	1,820	.5
Storden loam, 9 to 14 percent slopes	5,535	1.5
Storden loam, 14 to 18 percent slopes	1,555	.4
Storden loam, 18 to 25 percent slopes	600	.2
Storden-Salida complex, 5 to 9 percent slopes	250	.1
Storden-Salida complex, 9 to 14 percent slopes	385	.1
Storden-Salida complex, 14 to 18 percent slopes	180	[1]
Talcot clay loam, deep, 0 to 2 percent slopes	4,445	1.2
Truman silt loam, 0 to 2 percent slopes	360	.1
Truman silt loam, 2 to 6 percent slopes	365	.1
Wabash silty clay, 0 to 2 percent slopes	3,635	1.0
Wacousta silty clay loam, 0 to 1 percent slopes	710	.2
Wadena loam, deep, 0 to 3 percent slopes	580	.2
Waldorf silty clay loam, 0 to 2 percent slopes	1,055	.3
Watseka loamy fine sand, 0 to 2 percent slopes	365	.1
Webster silty clay loam, 0 to 2 percent slopes	29,335	8.2
Water	3,610	1.0
Gravel pits, made land, borrow pits	400	.1
Dump	5	[1]
Sewage pits	30	[1]
Total	359,040	100.0

[1] Less than 0.05 percent.

Figure 10.—**Grain sorghum on Spillville loam along the West Fork of the Des Moines River. The old meandering channel in the center has been filled. Trees in background, bordering the river, are on Spillville loam, channeled, 0 to 2 percent slopes.**

more detailed information about the technology and methods of soil mapping can be obtained from the Soil Survey Manual (*13*).

Biscay Series

The Biscay series consists of poorly drained, nearly level soils that have calcareous sand and gravel at a depth of 32 to 40 inches. These soils are on stream benches and in outwash areas and valley trains throughout the county. The native vegetation was marsh grasses, sedges, and prairie grasses that tolerate wetness.

In a representative profile the surface layer is black clay loam about 24 inches thick. The subsoil extends to a depth of 39 inches. The upper 12 inches is dark gray, olive gray, or gray, friable clay loam. Brown and black oxide concretions are common. The lower 3 inches is mottled olive gray gravelly sandy loam. The underlying material to a depth of 72 inches is mottled olive gray, calcareous, loose sand and gravel.

Biscay soils have moderate available water capacity. Permeability is moderate in the upper part and rapid or very rapid in the underlying sand and gravel. The surface layer is generally neutral. Available nitrogen is medium to low, available phosphorus is very low, and available potassium is very low to low. The organic-material content is high.

Biscay soils have a high water table. Where drained, they are mainly used for crops. Larger areas are sometimes managed separately, but most areas are small and are managed with adjacent soils.

Representative profile of Biscay clay loam, 0 to 2 percent slopes, 276 feet east and 980 feet north of southwest corner sec. 35, T. 95 N., R. 32 W.

Ap—0 to 8 inches, black (N 2/0) clay loam; cloddy parting to weak, fine, granular structure; friable; common fine roots; very few fine, reddish-brown (5YR 4/3) concretions (oxides); neutral; abrupt, smooth boundary.

A12—8 to 15 inches, black (N 2/0) clay loam; weak, fine, subangular blocky structure parting to moderate, fine and very fine, granular; firm; common fine roots; few fine, reddish-brown (5YR 4/3) concretions (oxides); neutral; gradual, smooth boundary.

A13—15 to 24 inches, black (10YR 2/1) clay loam; few fine, distinct, dark-gray (10YR 4/1) mottles in the upper part increasing to common in the lower part; weak, medium, prismatic structure parting to weak, medium and fine, subangular blocky; firm; few fine

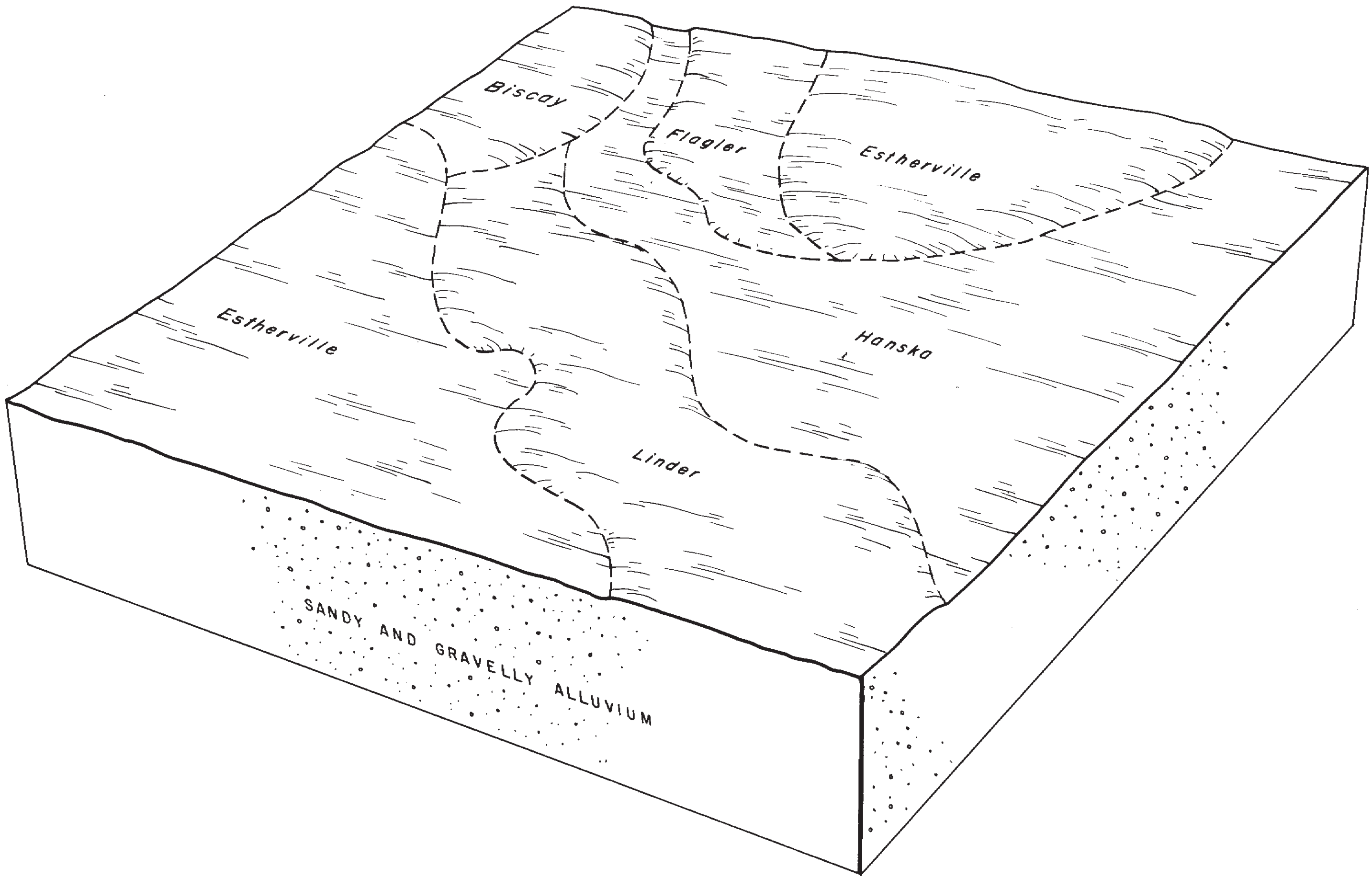

Figure 11.—**Pattern of soils and parent material in Estherville-Hanska-Linder association.**

roots; common fine, reddish-brown (5YR 4/3) concretions (oxides); neutral; clear, smooth boundary.

B21g—24 to 30 inches, gray (5Y 5/1) clay loam, 30 percent dark gray (10YR 4/1); dark gray (10YR 4/1) on faces of peds; few fine, faint, grayish-brown (10YR 5/2) mottles; moderate, medium, prismatic structure parting to moderate, fine, subangular blocky; firm; common 2- to 3-millimeter, brown (7.5YR 4/4) and black concretions (oxides); neutral; gradual, smooth boundary.

B22g—30 to 36 inches, olive-gray (5Y 5/2) clay loam; gray (5Y 5/1) on faces of peds; moderate, medium, prismatic structure parting to moderate, medium, subangular blocky; firm; common 2- to 3-millimeter, brown (7.5YR 4/4) and black concretions (oxides); few fine, yellowish-red (5YR 4/6) concretions (oxides); neutral; clear, wavy boundary.

IIB3g—36 to 39 inches, olive-gray (5Y 5/2) gravelly sandy loam, some gray (5Y 5/1) in upper parts; common fine, faint, olive (5Y 5/3) and light olive-brown (2.5Y 5/6) mottles; weak, medium, prismatic structure parting to weak, medium, subangular blocky; friable; common 2- to 3-millimeter, brown (7.5YR 4/4) and black concretions (oxides); few fine, yellowish-red (5YR 4/6) concretions (oxides); neutral; clear, wavy boundary.

IIC—39 to 72 inches, olive-gray (5Y 5/2) sand and gravel, some olive (5Y 5/3) and gray (5Y 5/1); single grained; loose; very few medium, black concretions (oxides); slight effervescence; mildly alkaline.

Biscay soils are generally neutral in the solum, but in places the lower part is moderately alkaline.

The A horizon ranges from about 14 to 24 inches in thickness. It is typically black (N 2/0 or 10YR 2/1) to very dark gray (10YR 3/1) clay loam, but in places it is silty clay loam or sandy clay loam.

The B horizon ranges from 2.5Y to 5Y in hue with value of 4 or 5 and chroma of 1 or 2. In some places, a few inches in the upper part are very dark gray (10YR 3/1). Typically, the B2 horizon is clay loam, but in places is loam. In some places, there is a B3g or lower horizon of sandy clay loam, gravelly loam, or gravelly sandy loam.

The C horizon is mixed, calcareous sand and gravel. The upper boundary is at a depth of 32 to 40 inches.

Biscay soils are associated on the landscape with Talcot and Cylinder soils. They are similar to Talcot soils, but are not calcareous throughout the solum. Biscay soils have a thicker and darker A horizon and a more gray and olive B horizon than Cylinder soils.

259—Biscay clay loam, deep, 0 to 2 percent slopes. This nearly level soil is in outwash areas and on stream benches. In most places, it is adjacent to the poorly drained Hanska, Talcot, and Mayer soils, the somewhat poorly drained Cylinder soils, and the well-drained Wadena soils. A few areas are near the very poorly drained Wabash soils. Individual areas range from 10 to 80 acres or more in size.

Included with this soil in mapping were areas where the depth to sand and gravel is slightly less than 32 inches. Other areas are included where the depth is as much as 48 inches and the dark surface layer is some-

what thicker than the one described as representative for the series. Also included were some areas where the subsoil is sandy loam and a few areas, one-half acre in size or less, of Okoboji soils, which are identified on the map by spot symbols.

This soil is poorly drained, and some areas are flooded during periods of high rainfall. Tile drains function well and can improve drainage, but in some places, an unstable substratum makes installation difficult. Where drainage is improved, this soil is well suited to row crops. If plowed in fall, it is subject to blowing unless the surface is protected. Larger areas of this soil are managed separately, but most areas are small and are managed with adjacent soils. Capability unit IIw–5, environmental planting group 2.

Blue Earth Series

The Blue Earth series consists of very poorly drained, nearly level soils in depressions and in old shallow lakebeds. Undrained areas are ponded most of the time. In a few places, the soils are in seepy areas along small meandering streams. These are calcareous soils that are mellow and friable. They are frequently referred to locally as "peat ground." Native vegetation was marsh grasses and sedges.

In a representative profile the surface layer is about 36 inches thick. It is mucky silt loam in the upper part and silty clay loam in the lower part. It is black in the upper part and grades to black and some very dark gray in the lower part. When dry, many areas are gray on the surface. The underlying material is black, dark-gray, and gray silty clay loam.

The Blue Earth soils have a high available water capacity and are moderately slowly permeable. Available nitrogen is generally high, and available phosphorus and potassium are very low. In some places trace elements are deficient for some crops. The organic-matter content is very high. The soils are moderately alkaline.

Blue Earth soils are slow to warm in spring, often delaying planting. Because they are low, frost often injures crops late in spring or early in fall. The water table is high unless the soils are artificially drained. Runoff from surrounding slopes often ponds during periods of heavy rainfall.

Most of the acreage is drained and cultivated. Other areas are in native swamp grasses and sedges. Where drained and well managed, the soils are suited to cultivation. They are subject to soil blowing if they are left bare after plowing. Most undrained areas are suitable for development as wildlife habitat.

Representative profile of Blue Earth mucky silt loam, 0 to 1 percent slopes, 1,180 feet west and 520 feet south of northeast corner sec. 17, T. 96 N., R. 33 W.

Lcop—0 to 8 inches, black (N 2/0) mucky silt loam; moderate, fine and very fine, granular structure; very friable; common fine roots; common snail shell fragments; strong effervescence; moderately alkaline; abrupt, smooth boundary.

Lco2—8 to 14 inches, black (N 2/0) mucky silt loam; moderate, fine and very fine, granular structure; very friable; common fine roots; common snail shell fragments; strong effervescence; moderately alkaline; clear, smooth boundary.

Lco3—14 to 18 inches, black (N 2/0) light silty clay loam; a few discontinuous horizontal bands of dark gray (5Y 4/1) to gray (5Y 5/1) in lower part; weak, medium, platy structure parting to weak, fine, granular; friable; common fine roots; common snail shell fragments; strong effervescence; moderately alkaline; gradual, smooth boundary.

Lco4—18 to 27 inches, black (N 2/0), very dark gray (5Y 3/1), and dark gray (5Y 4/1) silty clay loam; weak, coarse, prismatic structure; friable; many snail shell fragments; common, fine, tubular pores; violent effervescence; moderately alkaline; gradual, smooth boundary.

Lco5—27 to 36 inches, black (N 2/0), very dark gray (5Y 3/1), and dark gray (5Y 4/1) silty clay loam; weak, coarse, prismatic structure; friable; many snail shell fragments; common, fine, tubular pores; violent effervescence; moderately alkaline; gradual, smooth boundary.

Lco6—36 to 48 inches, black (N 2/0), very dark gray (5Y 3/1), and dark gray (5Y 4/1) silty clay loam; few, medium, faint, olive-gray (5Y 4/2 and 5Y 5/2) mottles; massive; friable; many snail shell fragments; common fine tubular pores; violent effervescence; moderately alkaline; gradual, smooth boundary.

Lco7—48 to 60 inches, gray (5Y 5/1) silty clay loam; massive; friable; many snail shell fragments; common fine tubular pores; violent effervescence; moderately alkaline.

The surface layer ranges from 26 to more than 40 inches in thickness. It ranges from black (N 2/0 or 10YR 2/1) to very dark brown (10YR 2/2) or very dark gray (10YR 3/1 or N 3/0). In some places a few plant fibers are at the surface and below the plow layer.

The underlying material ranges from black (N 2/0 or 10YR 2/1) to olive gray (5Y 4/2 to 5/2). It is generally silty clay loam, but in some places it is loam or clay loam. Lenses of sand are common, and a few areas are sandy along the perimeters of the depressions.

Blue Earth, Palms muck, and Okoboji soils are in depressions. Blue Earth soils are calcareous and have less organic matter than Palms muck. They are calcareous and have more organic matter than Okoboji soils.

511—Blue Earth mucky silt loam, 0 to 1 percent slopes. This nearly level soil is in depressions that formerly contained water most of the time and is also in former shallow lakebeds that have been drained. One areas a few hundred acres in size near Ruthven is in an old drained lakebed formerly known as Elbow Lake. Most areas are surrounded by a narrow band of Harps soils and are adjacent to areas of Nicollet, Webster, Canisteo, or Clarion soils. A few areas are adjacent to Storden soils. Areas are typically 10 to 30 acres in size.

Included with this soil in mapping are areas that contain many snail shells. Also included are areas where the organic layer is about 20 inches thick and a few areas where it is more than 40 inches thick.

Most areas are cultivated. Crop growth is only moderate because this soil is wet and the supply of available plant nutrients, especially phosphorus and potassium, is low. The supply of iron and some trace elements is low for some crops. Drained areas are used for corn. Small grain tends to lodge and produces poor quality grain. Legumes for hay do poorly and are often winterkilled. Partly drained areas are suited to permanent pasture of bluegrass, bromegrass, or reed canary-

grass. Undrained areas are only generally suited to wildlife habitat.

Crops grow fairly well where this soil is adequately drained, fertilized, and well managed. Adequate additions of phosphorus and potassium are particularly important. Crop growth is generally better in years of somewhat limited rainfall than in years when rainfall is above average. Much of the acreage is managed as separate fields. Small areas are managed with adjacent soils. Capability unit IIIw-2, environmental planting group 2.

Calco Series

The Calco series consists of poorly drained, nearly level, calcareous soils on bottom land. These soils formed in moderately fine textured silty alluvium under native marsh grasses, sedges, and prairie grasses that tolerate wetness. They occur throughout the county along small streams and on low parts of the first bottom along larger streams.

In a representative profile the surface layer is black silty clay loam about 28 inches thick. The subsoil, which extends to a depth of about 43 inches, is black and very dark gray silty clay loam. The substratum is black, very dark gray and olive gray, stratified silty clay loam, clay loam, and loamy sand. Olive or olive gray mottles are in the lower part of the subsoil and in the substratum.

Calco soils have a high available water capacity and are moderately slowly permeable. The water table is high unless the soil is artificially drained. Available nitrogen is medium to low, available phosphorus is very low to low, and available potassium is very low to low. Available iron is low in places. Calco soils are calcareous throughout the profile. They have an excess amount of lime and the surface layer is moderately alkaline. The organic-matter content is high. The surface layer puddles easily if worked when wet.

Calco soils are wet because of a high water table and flooding. Most areas are cultivated, but some are pastured. Individual areas are generally small and are managed with the adjacent soils.

Representative profile of Calco silty clay loam, 0 to 2 percent slopes, 93 feet north and 102 feet east of southwest corner NE1/4 sec. 24, T. 94 N., R. 31 W.

A11—0 to 8 inches, black (N 2/0) silty clay loam; moderate, fine, granular structure in the upper 4 inches and weak, fine, granular structure in the lower 4 inches; friable; many fine roots; slight effervescence; moderately alkaline; gradual, smooth boundary.

A12—8 to 14 inches, black (N 2/0) silty clay loam; very few, fine, faint, very dark gray (10YR 3/1) mottles; weak, very fine, granular structure; friable; common fine roots; a few, discontinuous, very thin strata of very fine sand; slight effervescence; moderately alkaline; gradual, smooth boundary.

A13—14 to 22 inches, black (N 2/0) silty clay loam; very few, fine, faint, very dark gray (10YR 3/1) mottles; weak, fine, subangular blocky structure parting to weak, very fine and fine, granular; friable; common fine roots; contains enough very fine sand to have a gritty feel; a very few, fine, dark-brown (7.5YR 3/2) concretions (oxides); slight effervescence; moderately alkaline; gradual, smooth boundary.

A14—22 to 28 inches, black (N 2/0) silty clay loam and a few black (5Y 2/1) peds; weak, fine, subangular blocky structure parting to weak, fine and very fine, granular; friable; a very few, fine, dark-brown (7.5YR 3/2) concretions (oxides); contains enough very fine sand to have a gritty feel; slight effervescence; moderately alkaline; gradual, smooth boundary.

B1—28 to 35 inches, black (N 2/0 and 5Y 2/1) silty clay loam; weak, fine, subangular blocky structure parting to weak, fine, granular in the upper part; firm; some mixing of olive (5Y 5/3); a very few fine dark-brown (7.5YR 3/2) concretions (oxides); a few snail shell fragments; contains enough sand to have a gritty feel; slight effervescence; moderately alkaline; clear, wavy boundary.

B2—35 to 43 inches, black (5Y 2/1) and very dark gray (5Y 3/1) silty clay loam; weak, fine, subangular blocky structure; firm; some mixing of olive (5Y 5/3); very few, fine, dark-brown (7.5YR 3/2) concretions (oxides); contains enough sand to have a gritty feel; strong effervescence; moderately alkaline; clear, wavy boundary.

C1—43 to 48 inches, black (5Y 2/1), very dark gray (5Y 3/1), and olive (5Y 5/3) silty clay loam; massive; firm; very few, fine, dark-brown (7.5YR 3/2) and black concretions (oxides); contains enough sand to have a gritty feel; strong effervescence; moderately alkaline; clear, wavy boundary.

C2—48 to 57 inches, olive-gray (5Y 5/2) clay loam; common, fine, faint, olive (5Y 4/3) mottles; massive; firm; common, fine, black and few, fine, dark-brown (5YR 3/2) concretions (oxides); a few very fine dark-gray (10YR 3/1) fills in old root channels; strong effervescence; moderately alkaline; clear, wavy boundary.

C3—57 to 66 inches, olive-gray (5Y 5/2) loamy fine sand; many, fine, distinct, olive-brown (2.5Y 4/4) and common, fine, distinct, olive (5Y 4/3) mottles; massive; very friable; many, fine, dark reddish-brown (2.5YR 3/4 to 5YR 3/4) concretions (oxides); strong effervescence; moderately alkaline.

The A horizon generally ranges from 24 to 36 inches thick. It is black (N 2/0) to very dark gray (10YR 3/1) light to medium silty clay loam. In some places, it has enough sand to have a gritty feel.

The B horizon is weakly developed. It is black (N 2/0 or 5Y 2/1), very dark gray (10YR 3/1, 5Y 3/1, or N 3/0), dark gray (10YR 4/1, 5Y 4/1, or N 4/0), or olive gray (5Y 4/2). It has value of 3 or less to a depth of 36 inches or more. Yellowish brown, olive yellow, or strong brown mottles are generally present. The texture is typically silty clay loam, but is clay loam in some places. The B horizon is not recognized in all places. The solum is 36 to 48 inches in most places.

The C horizon is generally mottled, calcareous silty clay loam, which has a gritty feel, or clay loam. In some places it is sandy below a depth of 40 inches.

Calco soils are similar to Colo soils, but are calcareous throughout their profile. They are more silty and darker colored to a greater depth than Canisteo soils. Calco and Colo soils are on similar landscapes. Calco and Canisteo soils have similar drainage.

733—Calco silty clay loam, 0 to 2 percent slopes. This nearly level soil is on the lowest part of broad and narrow first bottoms along the major streams and their tributaries. Where it is adjacent to the similar Colo soils, it is at a slightly lower elevation. It is the only soil on some narrow bottoms. Individual areas are typically 10 to 20 acres in size, but a few are larger.

Included in mapping are areas where this soil has as much as 10 inches of loamy overwash. Also included are a few areas where part or all the profile is heavy silty clay loam.

Unless drained and protected from overflow, this

soil is wet. Tile drains function well if outlets are satisfactory.

This soil is used for row crops and pasture. It is well suited to row crops if it is adequately drained and protected from flooding. Crop growth is moderate to good, depending on drainage and flood control. Areas where flooding is frequent or where drainage has not been improved are used for pasture.

Larger additions of phosphorus and potassium are needed on this soil than on the similar Colo soils, which are adjacent in places. This soil is generally managed with the adjacent soils on bottom land, but in places it is managed with the nearby soils on uplands. Capability unit IIw–2, environmental planting group 2.

Canisteo Series

The Canisteo series consists of nearly level, poorly drained soils. These soils formed under native marsh grasses and sedges in glacial till or waterworked sediments of glacial origin.

In a representative profile the surface layer is black silty clay loam that is high in sand content. It is about 16 inches thick and grades to very dark gray in the lower part. The subsoil extends to a depth of about 44 inches. It is mainly olive gray, friable clay loam that grades to sandy clay loam in the lower part. Some parts have common yellowish brown mottles. The substratum is olive gray clay loam mottled with yellowish brown and strong brown.

Canisteo soils have a high available water capacity. They are moderately permeable and are wet because of a high water table. Available nitrogen is medium to low, available phosphorus is very low to low, and available potassium is very low. These soils are moderately alkaline throughout the profile. Available iron is low in places because of the excess lime. The organic-matter content is high.

If drained, Canisteo soils are suited to row crops. Even when drained they dry out slowly after rains and puddle easily if worked when wet.

Areas of Canisteo soils vary in size; some are large. When drained, these soils are managed with the adjacent Harps, Webster, Nicollet, and Clarion soils. Unless protected, they are subject to soil blowing if plowed in fall.

Representative profile of Canisteo silty clay loam, 0 to 2 percent slopes, 198 feet south and 860 feet east of northwest corner NE¼ sec. 36, T. 95 N., R. 31 W.

Ap—0 to 7 inches, black (N 2/0) silty clay loam; moderate, fine, granular structure; friable; common fine and medium roots; few small pebbles; contains enough sand to have a gritty feel; slight effervescence; mildly alkaline; abrupt, smooth boundary.

A12—7 to 12 inches, black (N 2/0) silty clay loam mixed with very dark gray (5Y 3/1) peds in lower part; weak, fine, subangular blocky structure parting to moderate, fine and very fine, granular; friable; common fine and medium roots; few fine tubular pores; common coarse sand grains causes a gritty feel; some partly decayed organic matter; slight effervescence; mildly alkaline; clear, smooth boundary.

A3—12 to 16 inches, very dark gray (5Y 3/1) silty clay loam mixed with olive-gray (5Y 5/2 and 5Y 4/2) peds; weak, fine, subangular blocky structure parting to moderate and very fine granular and moderate, very fine, subangular blocky; friable; common fine roots; few fine tubular pores; contains enough sand to have a gritty feel; strong effervescence; moderately alkaline; clear, smooth boundary.

B1g—16 to 21 inches, mixed dark-gray (5Y 4/1), olive-gray (5Y 5/2), and 20 percent very dark gray (5Y 3/1) clay loam; some black (10YR 2/1) fills in old root channels; weak, medium, subangular blocky structure parting to moderate, fine, subangular blocky; friable; common fine roots; few small pebbles; few, fine, strong-brown and black concretions (oxides); strong effervescence; moderately alkaline; gradual, smooth boundary.

B21g—21 to 26 inches, olive-gray (5Y 5/2) and 30 percent dark-gray (5Y 4/1) clay loam; weak, fine, prismatic structure parting to weak, fine and very fine, subangular blocky; friable; common fine roots; few fine pebbles; few, fine, strong-brown and black concretions (oxides); strong effervescence; moderately alkaline; gradual, smooth boundary.

B22g—26 to 35 inches, olive-gray (5Y 5/2) and 10 percent gray (5Y 4/1) light clay loam; weak, fine and very fine, subangular blocky structure; friable; few fine roots; few fine tubular pores; few small pebbles; common, medium, black concretions (oxides) and a few, fine, strong-brown iron concretions (oxides); strong effervescence; moderately alkaline; gradual, smooth boundary.

B3g—35 to 44 inches, olive-gray (5Y 5/2) sandy clay loam; common, fine, distinct, yellowish-brown (10YR 5/6) mottles; weak, fine, subangular blocky structure; friable; few fine roots; few small pebbles; 1 inch sand lens at a depth of 40 to 41 inches; common, medium, manganese concretions (oxides); few strong-brown iron concretions (oxides); strong effervescence; moderately alkaline; gradual, smooth boundary.

Cg—44 to 60 inches, olive-gray (5Y 5/2) clay loam; common, medium, prominent, strong-brown (7.5YR 5/6) and yellowish-brown (10YR 5/6) mottles; massive; friable; few black stains on cleavage planes; few fine calcium carbonate accumulations in soft rounded masses; common, fine, strong-brown and few, fine, black concretions (oxides); strong effervescence; moderately alkaline.

The A horizon is about 16 to 24 inches thick. It is typically silty clay loam that has moderate sand content, but in some places it is clay loam. It is black (N 2/0) to very dark gray (10YR 3/1).

The B horizon ranges from dark grayish brown (2.5YR 4/2) to gray (5Y 5/1), olive gray (5Y 5/2), or olive (5Y 5/3). It is mainly silty clay loam that has moderate sand content or clay loam, but in some places it is loam or silt loam. Thin layers of sandy clay loam are in the lower B horizon in some profiles. In many profiles, yellowish-brown, strong-brown, or light olive-brown mottles are in the lower part.

The C horizon is typically gray (5Y 5/1), olive-gray (5Y 5/2), or light olive gray (5Y 6/2) clay loam or loam. In places it ranges to grayish brown (2.5Y 5/2) or olive (5Y 5/3 or 5/4). In some places there are thin layers of sandy clay loam or sandy loam. Mottles are like those in the B horizon. The soil is mildly alkaline or moderately alkaline throughout the profile.

Canisteo soils are calcareous throughout the profile, whereas Webster soils are not. They have a thicker, darker A horizon and are not so high in lime content as Harps soils. Harps soils are much lighter colored in the A horizon when dry. Canisteo soils lack the coarse-textured C horizon that is characteristic of Biscay and Talcot soils. Canisteo soils are associated on the landscape with Webster and Harps soils and are similar in drainage to Biscay and Talcot soils.

507—Canisteo silty clay loam, 0 to 2 percent slopes. This nearly level soil is on the undulating till plain. It is generally in areas bordering Okoboji soils (fig. 12)

Figure 12.—Surface drain, through field of corn and soybeans on Canisteo silty clay loam, 0 to 2 percent slopes, draining Okoboji soils in background.

or Palms muck. It is also in irregular low areas and in upland swales. It is frequently adjacent to Webster soils, which occupy the same landscape position. The adjacent Clarion, Nicollet, and Harps soils are at slightly higher elevations. Individual areas range from about 5 to more than 100 acres in size.

Included with this soil in mapping and identified on the soil map by spot symbols are areas of about one-half acre or less of Okoboji and Harps soils. Also included are a few areas where the substratum is distinctly stratified silt loam, fine sandy loam, loamy fine sand, or fine sand. Most of these areas are small, but an area of about 300 acres occurs in sections 30 and 31 of Vernon Township. An area of about 150 acres is in section 29 of Fairfield Township.

Most of the acreage is used for row crops and has either been artificially drained or partly drained. Tile drains function well. If this soil is drained adequately and well managed, crops grow well. If it is plowed when wet, the surface puddles easily and becomes cloddy and hard to work when dry. Fall plowing is common because freezing and thawing breaks the clods into better structure. Soil blowing is a hazard if large areas are fall plowed and the surface is left bare.

A few areas where drainage has not been improved are in permanent pasture. Some areas of this soil are managed separately, but most areas are managed with the surrounding soils. Capability unit IIw-1, environmental planting group 2.

Clarion Series

The Clarion series consists of well drained soils on the uplands. These soils are on convex knolls, undulating ridgetops, and side slopes. Slopes are 2 to 14 percent. Clarion soils formed in calcareous glacial till under native prairie grasses. Small rocks and pebbles are common.

In a representative profile the surface layer is black and very dark brown loam about 10 inches thick. Below this is about 4 inches of very dark grayish brown and dark brown loam. The subsoil is friable light clay loam and loam about 21 inches thick. The upper part is brown and the lower part is dark yellowish brown and yellowish brown. The substratum is yellowish-brown, friable, calcareous loam. Calcium carbonates and strong brown to red oxides or mottles are typically in the lower part of the subsoil and in the substratum.

Figure 13.—**Minimum tillage. The Clarion soil is the slope in the background. The Nicollet soil is in the foreground.**

Clarion soils have a high available water capacity and are moderately permeable. The water table is below a depth of 5 feet. Available nitrogen is low, available phosphorus is very low to low, and available potassium is very low. The organic-matter content is moderate. The surface layer and most of the subsoil are slightly acid or neutral. In most places the lower part of the subsoil and the substratum are mildly alkaline to moderately alkaline.

Nearly all the acreage is cultivated. These sloping soils erode when vegetation is sparse. Most areas are irregular in size and shape and are managed with adjacent soils. Only a few are large enough to be managed separately.

Representative profile of Clarion loam, 2 to 5 percent slopes, 243 feet north and 1,100 feet west of southeast corner sec. 20, T. 95 N., R. 33 W., on a 3 percent convex slope.

Ap—0 to 6 inches, black (10YR 2/1) heavy loam and few very dark brown (10YR 2/2) peds; moderate, fine, granular structure; friable; common fine roots; few fine tubular pores; neutral; abrupt, smooth boundary.

A12—6 to 10 inches, black (10YR 2/1) heavy loam and few dark-brown (10YR 2/2) peds; moderate, fine and medium, granular structure; friable; common fine roots; few fine tubular pores; neutral; clear, smooth boundary.

AB—10 to 14 inches, very dark grayish-brown (10YR 3/2) heavy loam A3 material; dark-brown (10YR 3/3) B1 material; many dark-brown (10YR 2/2) coats on faces of peds; weak, fine, subangular blocky structure parting to moderate, fine, granular; friable; common fine roots; few fine tubular pores; slightly acid; clear, smooth boundary.

B21—14 to 19 inches, brown (10YR 4/3) light clay loam; dark-brown (10YR 3/3) coats on some faces of peds; weak, fine, subangular blocky structure; friable; common fine roots; few fine tubular pores; neutral; gradual, smooth boundary.

B22—19 to 27 inches, dark yellowish-brown (10YR 4/4) light clay loam; faces of peds dark brown (10 YR 3/3) and brown (10YR 4/3); weak, fine and medium, subangular blocky structure; friable; common fine roots; few fine tubular pores; few, fine, yellowish-red (2.5YR 4/3) concretions (oxides); neutral; clear, smooth boundary.

B3—27 to 35 inches, yellowish-brown (10YR 5/4) loam; weak, medium to coarse, subangular blocky structure; friable; a few fine roots; common fine calcium carbonate accumulations in soft rounded masses; a few, fine, ¼- to ½-inch, yellowish-red (2.5 YR 4/8) concretions (oxides); strong effervescence; moderately alkaline; gradual, smooth boundary.

C—35 to 60 inches, yellowish-brown (10YR 5/4) loam; massive; friable; a few fine roots; common fine calcium carbonate accumulations in soft rounded masses; a few, fine, ¼- to ½-inch, yellowish-red (2.5YR 4/8) concretions (oxides); strong effervescence; moderately alkaline.

Unless eroded, the A horizon is 10 to 14 inches thick and is black (10YR 2/1), very dark brown (10YR 2/2), or very dark grayish brown (10YR 3/2). It is typically loam, but ranges to light clay loam. Thickness depends on slope gradient.

The B horizon is typically brown (10YR 4/3) to yellowish brown (10YR 5/4), but in many places is dark brown (10YR 3/3) in the upper part. In places it has a few mottles or oxides in the lower part. It ranges from light clay loam to loam, but thin layers of sandy loam, sandy clay loam, or silt loam are common. The B horizon is usually 10 to 30 inches thick. The depth to carbonates is generally 24 to 40 inches, but ranges from 18 to 50 inches. The B3 horizon generally extends into the calcareous material.

In some places pockets or thin lenses of sandy material are in the profile. The A horizon and upper layers of the B horizon range from neutral to medium acid.

Clarion soils are associated on the landscape with Nicollet and Storden soils. They have a thinner A horizon and a browner B horizon than Nicollet soils. They have a thicker A horizon and are deeper to carbonates than Storden soils, and they have a B horizon, which Storden soils lack. Clarion soils do not have a coarse textured C horizon, but are otherwise somewhat similar to Wadena soils.

138B—Clarion loam, 2 to 5 percent slopes. This gently sloping soil is on convex upland knolls and on ridgetops. It is undulating, and slopes are short and irregular. On the knolls it is upslope (fig. 13) from the adjacent Nicollet, Webster, Canisteo, and Okoboji soils. On ridgetops it is upslope from other Clarion soils or Storden soils. Areas are typically 10 to 25 acres in size, but range from 5 to 40 acres or more. This soil has the profile described as representative of the Clarion series.

Included with this soil in mapping were a few areas where the surface layer is 14 to 16 inches thick and areas of moderately eroded Clarion soils. Also included are some soils that are lower in sand content and have a higher clay content than is typical. Also included and identified on the soil map by spot symbols are a few small areas of the calcareous Storden soil, areas one-half acre or less of sandy soils and also of gravelly soils, and a few small areas of Rolfe soils. In the vicinity of West Bend and Rodman are a few included areas where layers of very fine sand occur below a depth of 35 inches.

Most areas are cultivated. A few are pastured. The soil is well suited to row crops if erosion is controlled. Erosion control is difficult in places, depending on the size and shape of the areas and the length and shape of slope. Crop growth is good. A few areas are managed separately, but most are managed with adjacent soils. Capability unit IIe-1, environmental planting group 1.

138C—Clarion loam, 5 to 9 percent slopes. This gently rolling soil is on knolls and on convex side slopes that mostly border small streams and upland drain-

ageways. It is upslope from Colo and Colo-Spillville soils on stream bottoms and in drainageways. In a few areas it is upslope from the steep Storden soils or other Clarion soils.

This soil has a profile similar to the one described for the series, but in many places the surface layer is thinner and depth to carbonates is somewhat less. Included in mapping and identified by symbols on the soil map are a few areas one-half acre or less of Storden soils and gravelly soils.

Most of the acreage is pasture and farmsteads. Part is cultivated. The soil is moderately suited to row crops if erosion is controlled. Erosion control is difficult in places because of the small size and shape of areas and the irregular slopes. In most places this soil is managed with the steeper Clarion and Storden soils. Capability unit IIIe–1, environmental planting group 1.

138C2—Clarion loam, 5 to 9 percent slopes, moderately eroded. This gently rolling soil is on knolls and convex side slopes. It is upslope from Storden, Nicollet, Webster, and Canisteo soils and in places other Clarion soils. Some areas border upland drainageways and small streams.

This soil has a profile similar to the one described as representative of the series, but the surface layer is typically very dark brown and about 7 inches thick. Plowing has exposed the brownish subsoil in places. Depth to carbonates is typically 24 to 32 inches.

Included with this soil in mapping and identified by spot symbols on the soil map are areas one-half acre or less of Storden soils, a few one-half acre areas of sandy soils, areas one-half acre or less of gravelly soils, and some conical shaped mounds of peat or muck that are referred to as "fens" by geologists (*2*). Examples of such mounds are in section 24, Highland Township.

Most areas are cultivated. A few are pastured. The soil is moderately suited to row crops. Erosion control is needed (fig. 14). In places it is difficult because of the size and shape of the areas, and the irregular slopes. Crop growth is good, but larger additions of fertilizer, especially nitrogen, are needed than on the uneroded Clarion soils. This soil is usually managed with other Clarion soils and in places with Nicollet and Webster soils. Capability unit IIIe–1, environmental planting group 1.

138D2—Clarion loam, 9 to 14 percent slopes, moderately eroded. This strongly sloping soil is on convex side slopes bordering stream valleys and drainageways of Colo, Calco, or Colo-Spillville soils. Other areas are upslope from Webster or Nicollet soils. Some areas of

***Figure 14.*—Parallel seeded backslope terraces and tile intake control runoff and erosion on Clarion loam, 5 to 9 percent slopes.**

this Clarion soil surround Marsh, Palms muck, or Okoboji soils. Less sloping Clarion soils are upslope.

This soil has a profile similar to the one described as representative of the series, but the plow layer is very dark brown or very dark grayish brown and is only about 7 inches thick. In places the subsoil is only 10 to 14 inches thick. Carbonates are at a depth of 18 to 30 inches. In some cultivated fields some of the brownish subsoil material has been mixed into the plow layer.

Included with this soil in mapping and identified by spot symbols on the soil map are areas one-half acre or less of Storden soil, gravelly areas of about one-half acre, and at the base of slopes, a few areas where the surface layer is more than 12 inches thick.

Most of the acreage is cultivated. Runoff is rapid, and erosion is a hazard (fig. 15). If erosion is controlled the soil is moderately suited to row crops. Erosion control is difficult in places because of the shape and small size of areas and the irregular slopes.

Crops grow well if fertility is maintained. More fertilizer, particularly nitrogen, is needed on this soil than on the uneroded Clarion soil. This soil is usually managed with the adjacent Storden soils and the less sloping Clarion soils. Capability unit IIIe-2, environmental planting group 1.

181B—Clarion-Estherville complex, 2 to 5 percent slopes. This gently undulating mapping unit is on irregular convex side slopes and ridges. It is adjacent to Clarion and Nicollet soils and to the steeper Clarion-Estherville complex. It is upslope from the Storden-Salida complex. Areas range from about 10 to 40 acres in size.

This complex is about 50 percent Clarion loam, 25 percent Estherville sandy loam, and 25 percent less extensive soils, which are extremely variable in texture and depth of leaching within short distances. Soils similar to the Dickman and Truman soils are two of the more important of those soils.

Included in mapping and identified by spot symbols on the soil map are areas one-half acre or less of Rolfe soils and areas where the surface layer is gravelly.

Most of the acreage is cultivated. Some is pastured, and some is used for hay crops. These soils are suited to row crops and could be used for row crops more often if they were protected from water erosion and soil blowing. Erosion control is difficult in places because of the size and shape of areas and the irregular slopes. Crop

Figure 15.—Erosion on Clarion loam, 9 to 14 percent slopes, moderately eroded, after a rain. Terraces, such as those shown in figure 14, control runoff and erosion.

growth is good on Clarion and Truman soils, but is generally poor or moderate on the rest. Capability unit IIe–1, environmental planting group 4.

181C2—Clarion-Estherville complex, 5 to 9 percent slopes, moderately eroded. This gently rolling mapping unit is on irregular convex side slopes and ridges. Most areas are adjacent to gently sloping Clarion soils and to the Clarion-Estherville complex, 2 to 5 percent slopes. Most are upslope from Storden-Salida complex. A few are upslope from Nicollet and Webster soils. Individual areas range from about 10 to 30 acres in size.

This mapping unit is about 50 percent Clarion loam, 25 percent Estherville sandy loam, and 25 percent less extensive soils, which are extremely variable in texture and depth of leaching within short distances. Soils similar to the Dickman and Truman soils are two of the most important of these soils. The Clarion, Estherville, Dickman, and Truman soils in this complex have a profile similar to the one described as representative of their respective series, but generally have a thinner surface layer. In places plowing and erosion have exposed some of the subsoil material at the surface.

Included in mapping and identified by spot symbols on the soil map are gravelly areas of about one-half acre or less.

Most areas are cultivated. Some are pastured, and some are used for hay crops. They are moderately suited to row crops if erosion is controlled. All are subject to water erosion, and some, particularly Dickman and Estherville soils, are readily subjective to blowing if the surface is left bare or if plant growth is sparse. Capability unit IIIe–4, environmental planting group 4.

638B—Clarion-Storden loams, 2 to 5 percent slopes. This gently sloping mapping unit is on convex upland knolls. It is undulating and has short, irregular slopes. It is typically upslope from Canisteo, Harps, Okoboji, or Blue Earth soils. Areas are about 4 to 8 acres in size.

In most areas this unit is about 50 percent Clarion loam and 50 percent Storden loam. In a few it is about 60 percent Storden loam. The Storden soil is typically upslope from the Clarion soil. It is similar to the one described as representative of the series, but the surface layer is a few inches thicker in places. Included in mapping are a few small areas where the substratum is silt loam.

Areas of this unit are used mostly for row crops, to which the soils are well suited if erosion is controlled. Erosion control, such as terraces and contouring, is difficult in places because of the shape and small size of areas and the associated soils. Crop growth is good. The soils in this unit are usually managed with the adjacent soils. Capability unit IIe–1, environmental planting group 3.

Colo Series

The Colo series consists of poorly drained, nearly level and gently sloping soils on bottom land. These soils formed in moderately fine textured silty alluvium under native marsh grasses, sedges, and prairie grasses that tolerate wetness. They occur throughout the county along small streams and on low parts of first bottoms along larger streams. They also are in narrow upland drainageways.

In a representative profile the surface layer is black silty clay loam about 33 inches thick. The subsoil is weakly expressed and is about 17 inches thick. It is black, firm silty clay loam and clay loam. The substratum is very dark gray light clay loam. Very dark gray and gray mottles are in the lower part of the subsoil and in the substratum.

Colo soils have a high available water capacity and are moderately slowly permeable. The water table is high unless the soil is artificially drained. Available nitrogen and phosphorus are medium to low, and available potassium is low. Reaction is neutral or slightly acid throughout the profile. The organic-matter content is high, but the surface puddles easily if worked when wet. In most areas overflow is common during periods of high rainfall.

Colo soils are wet because of a high water table and flooding. Most areas are cultivated, but some are in pasture. A few areas are large enough to be managed as individual fields. Other areas are managed with associated soils.

Representative profile of Colo silty clay loam, 0 to 2 percent slopes, 980 feet west and 360 feet north of southeast corner NE¼NE¼ sec. 26, T. 95 N., R. 32 W.

Ap—0 to 9 inches, black (N 2/0) silty clay loam; weak, fine and very fine, granular structure; firm; common fine roots; evident very fine sand grains on faces of peds; neutral; abrupt, smooth boundary.

A12—9 to 15 inches, black (N 2/0) silty clay loam; weak, fine and very fine, granular structure; firm; common fine roots; evident very fine sand grains on faces of peds; slightly acid; gradual, smooth boundary.

A13—15 to 22 inches, black (N 2/0) silty clay loam; weak, fine and very fine, subangular blocky structure parting to weak, medium, granular; firm; common fine roots; evident very fine sand grains on faces of peds; neutral; gradual, smooth boundary.

A14—22 to 33 inches, black (5Y 2/1) silty clay loam; few, fine, faint, very dark gray (5Y 3/1) mottles; weak, fine and medium, prismatic structure parting to weak, fine, subangular blocky and weak, medium, granular; firm; common very fine sand grains on faces of peds; a few, very fine, dark-brown (7.5YR 3/2) concretions (oxides) that are readily crushed; neutral; gradual, smooth boundary.

B2—33 to 42 inches, black (5Y 2/1) silty clay loam; few, fine, faint, very dark gray (5Y 3/1) mottles; weak, fine and medium, prismatic structure parting to weak, fine, subangular blocky and weak, medium, granular; firm; many very fine sand grains on faces of peds; contains enough sand to have a gritty feel; common, very fine, soft, dark-brown (7.5YR 3/2) and a very few, fine, soft, yellowish-red (5YR 4/6) concretions (oxides) that are readily crushed; neutral; gradual, smooth boundary.

B3—42 to 50 inches, black (10YR 2/1) clay loam; few, fine, faint, very dark gray (5Y 3/1) mottles; weak, medium, prismatic structure parting to weak, fine, subangular blocky and weak, medium, granular; firm; many very fine sand grains on faces of peds; few, very fine, dark-brown (7.5YR 3/2) and black concretions (oxides) that are readily crushed; neutral; gradual, smooth boundary.

C—50 to 66 inches, very dark gray (5Y 3/1) light clay loam; black (5Y 2/1) coatings on faces of peds; few, fine, faint, dark-gray (5Y 4/1) mottles; weak, medium, prismatic structure parting to very weak,

medium, subangular blocky; firm; few, very fine, black and dark-brown (7.5YR 3/2) concretions (oxides) that are readily crushed; neutral.

The A horizon is black (N 2/0) or very dark gray (10YR 3/1) and is typically 24 to 40 inches thick. It ranges from light to medium silty clay loam.

The B horizon is typically silty clay loam but is clay loam in places. Below a depth of 36 inches it ranges to dark gray (10YR 4/1 or 5Y 4/1) or olive gray (5Y 4/2). Strong brown, dark brown, or yellowish brown mottles are below a depth of 36 inches in some places. The B horizon is not recognized in all places.

The C horizon, below a depth of 50 inches, is commonly sandy clay loam, sandy loam, and sand.

Colo soils are similar to Calco soils but lack the calcium carbonates that are typical of those soils. They are finer textured throughout their profile and have less sand than Spillville soils. They are not so fine textured as Wabash soils. All of these soils formed in alluvium and are associated on the bottom lands of the county.

133—Colo silty clay loam, 0 to 2 percent slopes. This nearly level soil is on the bottom land of the major streams and their tributaries in the county. It is on both broad and narrow bottoms. In places single areas are large. This soil occurs with Spillville and Wabash soils on the broader bottoms. It is the only soil on some narrow bottoms. In a few areas the stream channels have been straightened.

This soil has the profile described as representative of the Colo series. Included in mapping are areas where it has as much as 10 inches of loamy overwash. Also included are a few areas where much of the profile is heavy silty clay loam.

Unless drained and protected from flooding, this soil is wet. Tile drains function well if outlets are satisfactory. A few old channels hold water during some seasons and interfere with use and management unless drained or filled.

This soil is used for both row crops and pasture. It is well suited to row crops if it is adequately drained and protected from flooding. Crop growth is moderate to good, depending on drainage and flood control. Areas where flooding is frequent or where drainage has not been improved are used for pasture. There are a few scattered trees. Many areas are managed as individual fields. Some are managed with the adjacent bottom land soils, and a few with the nearby upland soils. Capability unit IIw–2, environmental planting group 2.

133B—Colo silty clay loam, 2 to 4 percent slopes. This gently sloping soil is in narrow drainageways throughout the county. It is adjacent to areas of Nicollet and Clarion soils.

This soil has a profile similar to the one described as representative of the series, but the black surface layer is about 26 to 30 inches thick and is higher in sand content. The subsoil is very dark gray to olive gray silty clay loam. The underlying material, which is at a depth of about 40 to 50 inches, is calcareous clay loam. In a few places it contains thin lenses of silt or sand.

Included with this soil in mapping at the base of slopes were a few areas of soils that have a loamy surface layer and are somewhat poorly drained.

Most of the acreage is cultivated and managed with the adjacent Clarion and Nicollet soils. Some areas are frequently used as grass waterways. This soil is wet in most places and needs tile drainage because it receives runoff from the higher lying areas. It is well suited to row crops and if it is adequately drained, crop growth is good. Crops are damaged by runoff if rainfall is heavy, particularly when crops are small. Capability unit IIw–1, environmental planting group 2.

585B—Colo-Spillville complex, 2 to 5 percent slopes. This gently sloping mapping unit is in narrow drainageways throughout the county (fig. 16). The Colo soils are nearly level and are adjacent to the watercourse. The Spillville soils are near the base of slopes. Individual areas are long and narrow and are bordered by sloping to steep upland soils.

This complex is about 75 percent Colo soils and about 25 percent Spillville soils.

Included in mapping near the base of slopes were areas of soils that are loamy and well drained. Also included were a few areas of soils similar to Calco soils and areas where Colo soils have a surface layer of very dark grayish brown loamy recent sediments as much as 15 inches thick.

Runoff from surrounding uplands drains onto this unit. In places gullies have formed, and the drainageway is often uncrossable with farm machinery. Some areas are suitable as sites for constructing farm ponds and erosion control structures.

Part of the acreage is cultivated. If runoff from surrounding uplands is controlled, drainage is improved, and waterways are improved, much of the remaining acreage is suited to row crops. A few areas that are adjacent to steep soils are not suited to cultivated crops, but are suited to pasture. In some areas trees are growing along the waterways. These areas are excellent for wildlife. Capability unit IIw–2, environmental planting group 2.

Crippin Series

The Crippin series consists of nearly level, somewhat poorly drained soils on uplands. These soils are on slightly convex ridges. Slopes are 0 to 3 percent. Crippin soils formed in glacial till under native vegetation of prairie grasses. Small stones and pebbles are common.

In a representative profile the surface layer is black loam about 16 inches thick. It is mildly alkaline in the upper part and moderately alkaline in the lower part. The subsoil extends to a depth of about 35 inches and is friable loam. It is mixed black, very dark gray, and dark grayish brown in the upper part and dark grayish brown mottled with light olive brown in the lower part. The substratum is mottled dark grayish brown loam.

Crippin soils have a high available water capacity and are moderately permeable. The water table is at a depth of 2 to 4 feet during wet seasons. Available nitrogen is low to medium, available phosphorus is very low to low, and available potassium is very low. The surface layer is mildly alkaline or moderately alkaline. In places available iron is low. The organic-matter content is high.

These soils are wet during periods of high rainfall, but wetness does not limit crop growth. Some areas

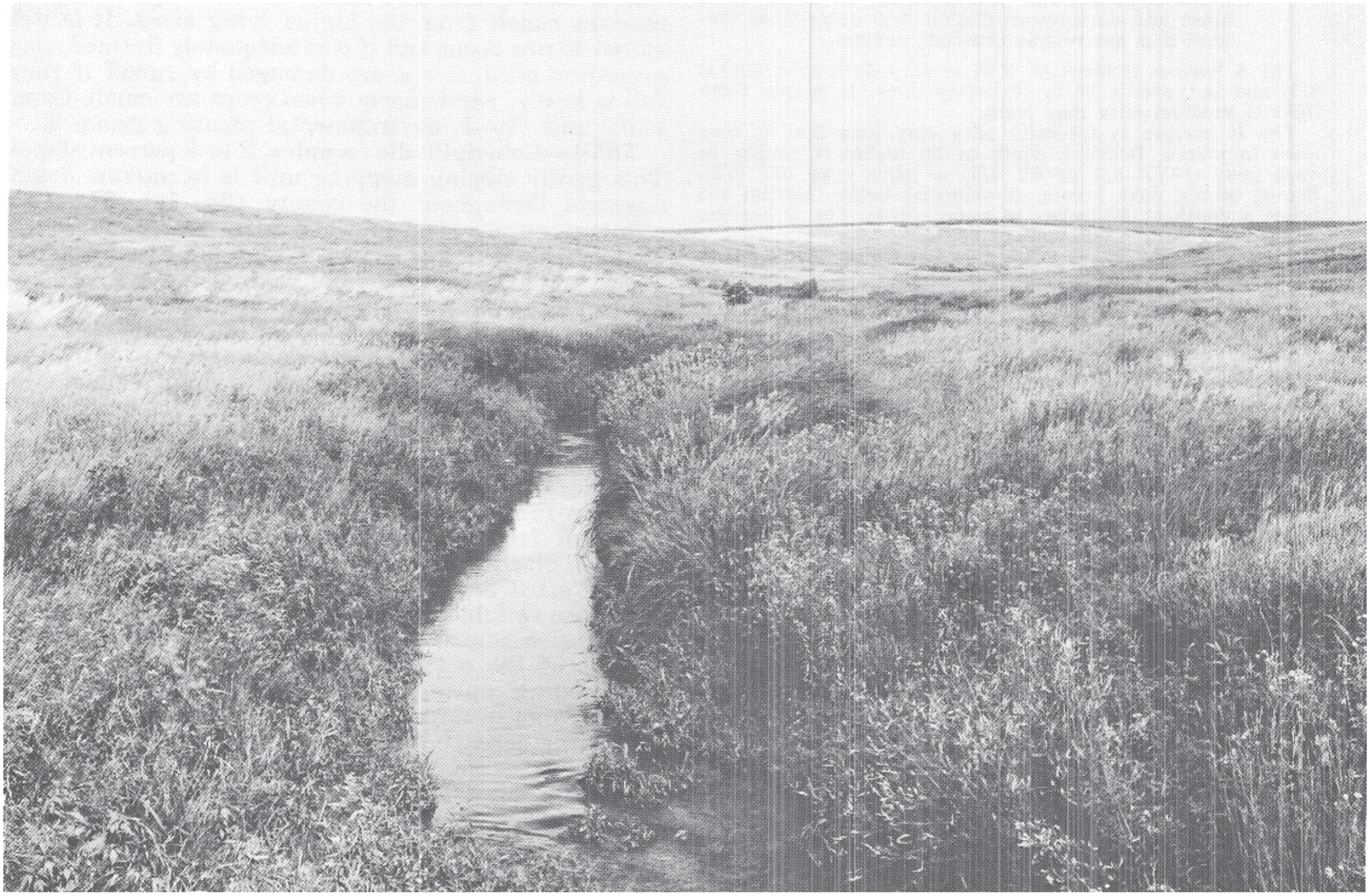

Figure 16.—**Narrow drainageway in Colo-Spillville complex, 2 to 5 percent slopes. Clarion and Storden soils are on the slopes.**

are artificially drained to improve timeliness of fieldwork. All the acreage is cultivated. If the soils are plowed in fall and left bare, soil blowing is a hazard. Because these areas are small and irregular in shape, they are managed with adjacent soils.

Representative profile of Crippin loam, 0 to 3 percent slopes, 44 feet south and 610 feet west of northeast corner NW¼ sec, T. 97 N., R. 32 W., on a low convex ridge of 2 percent slope:

Ap—0 to 7 inches, black (N 2/0) heavy loam; cloddy parting to moderate, fine, granular structure; friable; common fine roots; slight effervescence; moderately alkaline; abrupt, smooth boundary.

A12—7 to 11 inches, black (N 2/0) heavy loam; moderate, fine, granular and weak, fine, subangular blocky structure; friable; common fine roots; slight effervescence; mildly alkaline; gradual, smooth boundary.

A3—11 to 16 inches, black (N 2/0 and 10YR 2/1) loam; moderate, fine, granular structure and weak, fine, subangular blocky; friable; common fine roots; strong effervescence; moderately alkaline; gradual, smooth boundary.

B1—16 to 20 inches, mixed black (10YR 2/1), very dark gray (10YR 3/1), and dark grayish-brown (10YR 4/2) loam, very dark grayish brown (10YR 3/2) kneaded; weak, fine, subangular blocky structure parting to moderate, fine, granular; friable; common fine roots; strong effervescence; moderately alkaline; gradual, smooth boundary.

B2—20 to 27 inches, dark grayish-brown (10YR 4/2) loam, dark grayish-brown (10YR 4/2) kneaded; about 20 percent very dark gray (10YR 3/1) peds and few, fine, faint, brown (10YR 5/3) mottles; weak, fine, subangular blocky structure; friable; common fine roots; strong effervescence; moderately alkaline; gradual, smooth boundary.

B3—27 to 35 inches, dark grayish-brown (10YR 4/2) loam; common, fine, distinct, light olive-brown (2.5Y 5/4) mottles; weak, fine, subangular blocky structure; friable; common fine roots; some mixing of light olive brown (2.5Y 5/4) in lower part; strong effervescence; moderately alkaline; gradual, smooth boundary.

C—35 to 60 inches, dark grayish-brown (10YR 4/2) loam; mottles are common fine distinct light olive brown (2.5Y 5/4) and light brownish gray (2.5Y 6/2), and many fine distinct yellowish brown (10YR 5/6); massive; friable; common, fine, yellowish-red to strong-brown concretions (oxides); strong effervescence; moderately alkaline.

The Ap or A1 horizon is typically black (N 2/0 or 10YR 2/1) but ranges to very dark gray (10YR 3/1). The A3 horizon ranges from black (10YR 2/1 or N 2/0) to very dark grayish brown (10YR 3/2). The total thickness of the A horizon is 10 to 20 inches. The texture is clay loam or loam.

The B horizon is light to medium clay loam or loam. The

B2 horizon is dark grayish brown (10YR or 2.5Y 4/2). The B1 horizon is very dark gray (10YR 3/1) or very dark grayish brown (10YR 3/2) in many profiles, and in some the B3 horizon is grayish brown (2.5Y 5/2) or olive brown (2.5Y 5/4).

The C horizon has hue of 10YR to 5Y, value of 4 or 5, and chroma of 2 to 4.

Crippin soils are mildly alkaline or moderately alkaline in the A horizon and the upper part of the B horizon and moderately alkaline in the lower part and in the C horizon.

Crippin and Nicollet soils formed in similar parent material. In contrast, Crippin soils are calcareous throughout. In contrast with Cylinder soils, they do not have sand and gravel in the C horizon. All have similar drainage.

655—Crippin loam, 0 to 3 percent slopes. This nearly level soil is mainly on slightly convex knolls within large areas of Canisteo soils, but some areas border Okoboji or Harps soils. Areas are generally 5 to 10 acres in size, but a few areas are as large as about 30 acres.

Included with this soil in mapping were a few areas of soils that have a thinner surface layer and are similar to Storden soils. In section 26 of Fern Valley, a few areas are included where stratified silts and very fine sands are below a depth of about 30 inches.

Almost all the acreage is cultivated. Erosion generally is not a problem. If the soil is plowed in fall, soil blowing may be a problem. Crippin soils generally are not tile drained, but in some areas artificial drainage would improve timeliness of fieldwork. The supply of available phosphorus and potassium is generally lower than on Nicollet soils. This soil is well suited to row crops. It is managed with the adjacent Canisteo, Harps, and Okoboji soils. Capability unit I-1, environmental planting group 3.

Cylinder Series

The Cylinder series consists of nearly level, somewhat poorly drained soils mainly on benches and on a large outwash plain near the town of Cylinder. Slopes are 0 to 2 percent. The native vegetation was prairie grasses.

In a representative profile the surface layer is black loam about 15 inches thick. The subsoil is about 22 inches thick. It is dark grayish brown and very dark grayish brown friable loam in the upper part and dark grayish brown, yellowish brown, and light olive brown sandy loam in the lower part. The substratum is yellowish brown, dark grayish brown, and dark yellowish brown, loose calcareous sand and gravel.

These soils have a moderate available water capacity. Above the sand and gravel, they are moderately permeable, but in the sand and gravel they are rapidly permeable to very rapidly permeable. In spring the seasonal water table may be within 2 feet of the surface, but by midsummer crops lack available water unless rains are timely. Available nitrogen is low, available phosphorus is very low, and available potassium is very low to low. The organic-matter content is high. The surface layer is generally neutral or slightly acid. Some areas are more acid and need lime.

Most of the acreage is cultivated. Because most areas are small, these soils are usually managed with the adjacent soils.

Representative profile of Cylinder loam, deep, 0 to 2 percent slopes, 100 feet south and 40 feet east of northwest corner sec. 27, T. 95 N., R. 32 W.

Ap—0 to 9 inches, black (N 2/0) loam; cloddy parting to moderate, fine, granular structure; friable; few, medium, dark-brown concretions (oxides); neutral; abrupt, smooth boundary.

A12—9 to 15 inches, black (N 2/0 and 10YR 2/1) loam; moderate, fine, granular structure and some weak, subangular blocky; friable; common, medium, dark-brown concretions (oxides); neutral; gradual, smooth boundary.

B1—15 to 20 inches, dark grayish-brown (2.5Y 4/2) and very dark grayish-brown (2.5Y 3/2) loam; few black (10YR 2/1) peds in upper part; few, fine, faint, brown (10YR 4/3) and light olive-brown (2.5Y 5/4) mottles; weak, fine and medium, subangular blocky structure parting to weak, fine, granular; friable; common, medium, black concretions (oxides) and a few, fine brown (7.5YR 4/4) concretions (oxides) that are readily crushed; neutral; gradual, smooth boundary.

B21—20 to 26 inches, dark grayish-brown (2.5Y 4/2) loam; common, fine, distinct, light olive-brown (2.5Y 5/4) mottles; weak, fine and medium, subangular blocky structure; friable; common, medium, black concretions (oxides) and a few, fine, brown (7.5YR 4/4) accumulations (oxides) that are readily crushed; neutral; gradual, smooth boundary.

B22—26 to 32 inches, dark grayish-brown (2.5Y 4/2) loam; common, fine, distinct, light olive-brown (2.5Y 5/4) mottles grading in lower part to common, fine and medium, distinct, yellowish brown (10YR 5/4); weak, medium, subangular blocky structure; friable; common, medium, moderately hard, black concretions (oxides) and a few, fine, brown (7.5YR 4/4) concretions (oxides) that are readily crushed; neutral; gradual, smooth boundary.

B3—32 to 37 inches, dark grayish-brown (2.5Y 4/2), light olive-brown (2.5Y 5/4), and yellowish-brown (10YR 5/4) sandy loam; very weak, medium and coarse, subangular blocky structure; very friable; common, medium, moderately hard, black concretions (oxides) and a few, fine, soft-brown (7.5YR 4/4) accumulations (oxides); neutral; clear, wavy boundary.

IIC1—37 to 41 inches, dark grayish-brown (2.5Y 4/2), dark yellowish-brown (10YR 4/4), and yellowish-brown (10YR 5/4) sand and gravel; slightly cemented to single grained; loose; common, fine to medium, moderately hard, black and dark-brown concretions (oxides); few accumulations of calcium carbonate in soft rounded masses; slight effervescence; moderately alkaline; clear, wavy boundary.

IIC2—41 to 60 inches, brown (10YR 5/3) and yellowish-brown (10YR 5/4) sand and gravel; single grained; loose; common, fine to medium, black and brown concretions (oxides); few accumulations of calcium carbonate in soft rounded masses; slight effervescence; moderately alkaline.

The A horizon ranges from about 10 to 24 inches in thickness. It is typically black (10YR 2/1) or very dark brown (10YR 2/2) and grades to very dark grayish brown (10YR–2.5Y 3/2) to very dark gray (10YR 3/1) in the lower part.

The B horizon is typically dark grayish brown (2.5Y 4/2) or grayish brown (2.5Y 5/2), but is very dark grayish brown (10YR–2.5Y 3/2) in the upper part and is brown (10YR 4/3) to olive brown (2.5Y 4/4) in the lower part. Yellowish brown or light olive brown mottles are common. The B2 horizon is loam or light clay loam, which grades to sandy clay loam, sandy loam or loamy sand in the B3 horizon.

The A and B horizons are typically slightly acid to neutral. In some profiles the A horizon is medium acid, and in some the B3 horizon is mildly alkaline.

The underlying sand and gravel is at a depth of 32 to 40 inches. The coarse material is typically calcareous. The

upper few inches is neutral in a few places. This material is from about 3 to many feet thick.

Cylinder soils have a thicker A horizon than Wadena soils and are grayish brown in the B horizon. They lack the grayish B horizon that is typical of Biscay soils. They are similar to Nicollet soils, except for the sand and gravel C horizon. Cylinder soils formed in parent materials similar to those of Wadena and Biscay soils and have about the same drainage as Nicollet soils.

203—Cylinder loam, deep, 0 to 2 percent slopes. This nearly level soil is in outwash areas and on stream benches generally adjacent to Linder, Wadena, or Biscay soils. Slopes are slightly convex to slightly concave. Individual areas typically range from about 5 to 20 acres.

Included with this soil in mapping are areas where the surface layer is a few inches thicker than is typical and a few areas where the depth to sand and gravel is more than 40 inches or less than 32 inches. Also included are a few areas where the profile is slightly calcareous throughout and other areas where the surface layer is medium acid.

Most areas are cultivated, but a few areas are pastured. Row crops grow well and are well suited. Some areas are slightly wet in years when rainfall is above normal. Crops lack adequate moisture by midsummer unless rains are timely. These soils are generally managed with the adjacent soils. Capability unit I–2, environmental planting group 1.

Dickman Series

The Dickman series consists of somewhat excessively drained soils. These soils formed under prairie grasses in sandy material deposited by wind or in glacial drift that has been modified and moved by wind. The soils are mainly in the uplands and on high benches near the larger streams and lakes. Areas are generally oriented in the northwest-southeast direction. Slopes are 0 to 5 percent.

In a representative profile the surface layer is black and very dark brown sandy loam about 15 inches thick. The subsoil extends to a depth of about 52 inches. The upper 15 inches is brown, dark brown, and very dark grayish brown, and the next 16 inches is brown. The texture is loamy fine sand and medium sand. The lower 6 inches of the subsoil is very dark grayish brown silty clay loam. The substratum is grayish brown and yellowish brown, massive silt loam.

The Dickman soils have moderate available water capacity and are rapidly permeable. Available nitrogen and phosphorus are generally low, and available potassium is very low to low. The organic-matter content is low. These soils are typically neutral or slightly acid. They warm up rapidly in spring and can be worked soon after rains. They erode rapidly if the surface layer is bare or vegetation is sparse.

Most of the acreage is cultivated because the small areas are usually closely associated with soils that are better suited to cultivation. These soils are managed with the associated soils.

Representative profile of Dickman fine sandy loam, loamy substratum, 2 to 5 percent slopes, 85 feet south and 440 feet west of northeast corner SE¼SE¼ sec. 1, T. 96 N., R. 33 W., on top of a convex ridge.

Ap—0 to 7 inches, black (10YR 2/1) fine sandy loam; weak, medium, granular structure; very friable; common fine roots; estimated 5 percent medium sand; slightly acid; abrupt, smooth boundary.

A12—7 to 15 inches, very dark brown (10YR 2/2) fine sandy loam; black (10YR 2/1) coats on faces of peds; weak, medium, granular structure; very friable; common fine roots; a few dark-brown (10YR 3/3) worm casts; estimated 5 percent medium sand; slightly acid; clear, smooth boundary.

B1—15 to 22 inches, dark-brown (10YR 3/3) and very dark grayish-brown (10YR 3/2) loamy fine sand; common very dark brown (10YR 2/2) coats on faces of peds; some weak, fine, subangular blocky structure parting to weak, medium, granular; very friable; few fine roots; estimated 10 percent medium sand; a few dark-brown (10YR 3/3) and dark yellowish-brown (10YR 3/4) worm casts; neutral; gradual, smooth boundary.

B21—22 to 30 inches, dark-brown (10YR 3/3) and brown (10YR 4/3) loamy fine sand and medium sand; few very dark grayish-brown (10YR 3/2) peds; weak, medium, subangular blocky structure; very friable; a few fine roots; neutral; gradual, smooth boundary.

B22—30 to 39 inches, brown (10YR 4/3) medium and fine sand; brown (10YR 3/3) coats on faces of peds; weak, coarse, subangular blocky structure; very friable; estimated 5 percent coarse sand; neutral; gradual, smooth boundary.

B31—39 to 46 inches, brown (10YR 4/3) medium and fine sand; few dark brown (10YR 3/3) coats on faces of peds; a few, medium, faint, grayish-brown (10YR 5/2) mottles; very weak, coarse, subangular blocky structure; a few, fine, brown (7.5YR 4/4) concretions (oxides); neutral; clear, smooth boundary.

IIB32—46 to 52 inches, very dark grayish-brown (10YR 3/2) silty clay loam; very dark gray (5Y 3/1) and dark gray (5Y 4/1) coats on faces of peds; few, fine, faint-brown (10YR 4/3) mottles; moderate, very fine, subangular blocky structure; firm; common, fine, dark-brown (7.5YR 3/2) concretions (oxides); neutral; gradual, smooth boundary.

IIC—52 to 63 inches, 40 percent grayish-brown (10YR 5/2) and 60 percent yellowish-brown (10YR 5/4) heavy silt loam; common, fine, faint, brown (7.5YR 4/4) mottles; massive; friable; neutral.

The A horizon is 10 to 20 inches thick, but in a few places it is thinner because of erosion. It is black (10YR 2/1), very dark gray (10YR 3/1), very dark brown (10YR 2/2), or very dark grayish brown (10YR 3/2). It is typically loam or fine sandy loam.

The B2 horizon ranges from dark brown (10YR 3/3) to dark yellowish brown (10YR 4/4) in the upper part and from brown (10YR 4/3) to yellowish brown (10YR 5/4 to 5/6) in the lower part. The B1 horizon is typically loamy fine sand, and the B2 and B3 horizons are loamy fine sand and medium sand or fine and medium sand. In Palo Alto County, the sandy materials generally are about 40 to 50 inches thick. Stratified loamy sediments or loamy glacial till are beneath. In some places, however, the sands are as much as about 6 feet thick. In places the B3 horizon extends into the loamy material.

Dickman soils in Palo Alto County are mainly neutral or slightly acid in the solum, but range to medium acid.

Dickman soils are leached throughout, as compared to Salida soils, which are calcareous at or near the surface. They are not so gravelly as Salida soils. They lack the gravel that is in the C horizon of Estherville sandy loam. They have textures similar to the Watseka sandy loam, which has a grayer B horizon and is underlain by coarser material. All of these soils are similar in having a moderately coarse or coarse texture and low or moderate available water capacity.

324—Dickman fine sandy loam, loamy substratum, 0 to 2 percent slopes. This nearly level soil is mainly

on sandy ridges in the uplands. Other areas are on high benches. This soil is in association with other Dickman soils and with Clarion and Storden soils. It has a profile similar to the one described as representative of the series, but the surface layer is generally a few inches thicker. Included in mapping were some places where the loamy substratum is at a depth of less than 40 inches.

Most of the acreage is cultivated. Crop growth is poor or moderate, especially in years when rainfall is below average or rains are not timely. Soil blowing is a hazard because the surface dries quickly after tillage. Blowing sand sometimes damages young plants. A few areas are large enough to be managed separately, but most areas are managed with the adjacent soils. Capability unit IIIs–1, environmental planting group 4.

324B—Dickman fine sandy loam, loamy substratum, 2 to 5 percent slopes. This gently sloping soil is in uplands and on high benches. Most areas are small and are with other Dickman soils and with Clarion and Storden soils. This soil has the profile described as representative of the series. Included in mapping were some places where the loamy substratum is at a depth of less than 40 inches.

Most areas are cultivated. A few are pastured. Crop growth is poor or moderate, especially in years when rainfall is below average or rains are not timely. This soil is subject to both soil blowing and water erosion. Soil blowing is often a hazard because the surface dries quickly after tillage. Blowing sand damages young plants.

In building terraces, deep cuts may expose the sand subsoil, which is low in organic-matter content, fertility, and available water capacity. A few areas are large enough to be managed separately, but most areas are managed with the adjacent soils. Capability unit IIIe–3, environmental planting group 4.

Estherville Series

The Estherville series consists of excessively drained soils. These soils are on nearly level glacial outwash plains, on stream benches, and on knobs or kames in glacial moraines. Slopes range from 0 to 9 percent. Estherville soils formed under native prairie grasses in medium textured to coarse textured outwash that is underlain by calcareous sand and gravel at a depth of 15 to 30 inches.

In a representative profile the surface layer is black grading to black and very dark brown loam about 11 inches thick. The subsoil extends to a depth of about 30 inches. The upper part is very dark brown and dark brown sandy loam. The lower part is dark brown, brown, and very dark grayish brown gravelly sandy loam. The substratum is mixed dark yellowish brown, brown, and yellowish brown, loose, calcareous sand and gravel.

Estherville soils have a low or very low available water capacity, depending on the texture and the depth to sand and gravel. They are rapidly permeable or moderately rapidly permeable above the sand and gravel, but rapidly or very rapidly permeable in the sand and gravel. Available nitrogen is low, and available phosphorus and potassium are generally very low. Reaction ranges from neutral to medium acid. The organic-matter content is low. Crops often lack adequate available water. These soils warm up rapidly in spring and can be worked soon after rains. They erode rapidly, particularly from soil blowing, if the surface is left bare.

Estherville soils are used for pasture, row crops, and forage crops. They are better suited to pasture or forage crops than to row crops because of their low or very low available water capacity. Some areas are managed as separate fields. Smaller areas in cultivated fields are managed with the associated soils or are left in grass and then grazed in fall along with the crop residue.

Representative profile of Estherville loam, 0 to 2 percent slopes, 273 feet north and 246 feet east of southwest corner SE¼ sec. 30, T. 96 N., R. 31 W.

Ap—0 to 7 inches, black (10YR 2/1) loam; cloddy parting to moderate, fine, granular structure and moderate, medium, granular; friable; common fine roots; common coarse sand and gravel particles; neutral; abrupt, smooth boundary.

A12—7 to 11 inches, black (10YR 2/1) and very dark brown (10YR 2/2) loam; moderate, fine, granular structure; friable; common fine roots; few gravels; common sand grains; neutral; clear, smooth boundary.

B1—11 to 16 inches, very dark brown (10YR 2/2) fine sandy loam; black (10YR 2/1) coats on faces of peds; few very dark grayish-brown (10YR 3/2) peds in lower part; weak, fine, subangular blocky structure parting to moderate, fine, granular; friable; common fine roots; few gravels; slightly acid; clear, smooth boundary.

B2—16 to 24 inches, dark-brown (7.5YR 3/2) and dark-brown (10YR 3/3) sandy loam; few very dark brown (10YR 2/2) and brown (10YR 4/3) peds; weak, fine, subangular blocky structure parting to weak, fine, granular; friable; common fine roots; few fine gravels and small rocks; slightly acid; gradual, smooth boundary.

IIB3—24 to 30 inches, mixed brown (10YR 4/3), dark-brown (10YR 3/3), and very dark grayish-brown (10YR 3/2) gravelly sandy loam; weak, medium, subangular blocky structure; very friable; common fine roots; common fine and coarse gravels; few small rocks; neutral; clear, smooth boundary.

IICca—30 to 60 inches, mixed brown (10YR 4/3), dark yellowish-brown (10YR 4/4), and yellowish-brown (10YR 5/4) sand and gravel; single grained; few fine roots; strong effervescence; moderately alkaline.

The A horizon ranges from 9 to 18 inches in thickness. The A1 horizon is typically black (10YR 2/1), but in some places it is very dark brown (10YR 2/2) or very dark gray (10YR 3/1). The A3 horizon is typically very dark gray (10YR 3/1), but in some places it is very dark grayish brown (10YR 3/2) or dark brown (10YR 3/3). The A horizon is sandy loam or light loam, and in some places is 5 to 8 percent gravel.

The B2 horizon is dark brown (7.5YR 3/2 or 10YR 3/3) to brown (10YR 4/3), or dark yellowish brown (10YR 3/4 to 10YR 4/4). In some profiles dark brown (7.5YR 3/2 to 7.5YR 4/4) makes up part or all of the matrix color. The faces of peds are typically darker than the interiors. The B2 horizon is about 5 to 15 percent gravel, and the B3 horizon as much as 20 percent. The B3 horizon is sandy loam, coarse sandy loam, or loamy sand. The A and B horizons are typically neutral or slightly acid, but range to medium acid.

The underlying sand and gravel in the loams is at a depth of 24 to 30 inches. In the sandy loams it is at a depth of 15 to 30 inches. The IIC horizon is commonly grayish

brown (10YR 5/2), yellowish brown (10YR 5/4 to 10YR 5/6), brown (10YR 4/3 or 7.5YR 4/4), or dark yellowish brown (10YR 4/4). It is typically coarse and very coarse sand that is 10 to 35 percent gravel. In some places it is loamy sand and gravel. The IIC horizon is typically calcareous throughout, but the upper few inches are leached in places.

Estherville soils have a thinner, coarser textured B horizon and are shallower over gravel than Wadena soils, which are nearby, and formed in similar parent material. They have a leached B horizon that is finer textured than that of Salida soils, which formed in similar parent material. They contain more coarse material and have a coarser textured IIC horizon than Dickman soils, which have a similar textured A horizon.

34—Estherville sandy loam, 0 to 2 percent slopes. This nearly level soil is in outwash areas and on stream benches, generally with other Estherville soils or with Wadena, Cylinder, Linder, Dickman, and Flagler soils. Slopes are slightly convex. Individual areas are typically 15 to 30 acres, but a few areas are as much as 100 acres in size.

This soil has a profile similar to the one described as representative of the series, but the surface layer is sandy loam and the depth to calcareous sand and gravel is typically 15 to 30 inches.

Included with this soil in mapping are areas where the subsoil is strong brown and the depth to the calcareous sand and gravel substratum is about 36 inches. Also included are a few areas where the surface layer is light loam.

Most of the acreage is cultivated. Many areas are used for hay crops and as rotation pasture. This soil is suited to row crops. Crop growth is poor or moderate, especially in years when rainfall is below average or rains are not timely. Soil blowing is a hazard because the surface dries quickly after tillage. Blowing sand sometimes damages young plants. In many areas this soil is managed separately, but in small areas it is managed with the adjacent soils. Capability unit IIIs–1, environmental planting group 4.

34B—Estherville sandy loam, 2 to 5 percent slopes. This gently sloping soil is in outwash areas and on stream benches, generally with other Estherville soils or with Wadena, Cylinder, and Dickman soils. Slopes are generally short and convex. Individual areas are typically 5 to 15 acres in size.

This soil has a profile similar to the one described as representative of the series, but the surface layer is about 4 inches thinner and is sandy loam. In a few places, erosion and plowing have exposed the browner subsoil, and some of these eroded areas are gravelly at the surface. The depth to calcareous sand and gravel is typically 15 to 26 inches.

Included with this soil in mapping are areas where the subsoil is strong brown and the depth to the calcareous sand and gravel substratum is slightly more than 30 inches.

This soil is used for hay, rotation pasture, and row crops. Crop growth is poor or moderate, especially in years when rainfall is below average or rains are not timely.

Terraces should not be constructed because the sand and gravel substratum is likely to be exposed. Erosion is a hazard when row crops are grown. Soil blowing is a hazard when this soil is used for row crops, because the surface layer dries quickly after tillage. Blown sand damages young plants in some years. Some areas are managed with the adjacent soils. Capability unit IIIe–3, environmental planting group 4.

34C2—Estherville sandy loam, 5 to 9 percent slopes, moderately eroded. This moderately sloping soil is on side slopes between the soils of the bottoms and other Estherville soils or Wadena, Dickman, or Cylinder soils that are upslope. Other areas are on outwash plains where they are adjacent to Wadena, Storden, Clarion, or Salida soils. Slopes are generally short and convex. Individual areas are typically 5 to 10 acres in size.

This soil has a profile similar to the one described as representative of the series, but the surface layer is sandy loam instead of loam. The surface layer is a very dark grayish brown plow layer in most places. Erosion and plowing have exposed the lighter colored subsoil in places. Included in mapping are areas where the surface layer is loam.

This soil is used for hay, pasture, and row crops. It is better suited to hay or pasture because it has very low available water capacity and soil blowing and water erosion are hazards when the soil is tilled. Growth of row crops is generally poor, but the growth of hay crops is often moderate unless rainfall is below normal. In most places this soil is managed with adjacent soils. Capability unit IIIe–4, environmental planting group 4.

72—Estherville loam, 0 to 2 percent slopes. This nearly level soil is in outwash areas and on stream benches, generally with other Estherville soils and with Wadena, Cylinder, Dickman, and Linder soils. The surface is plane to slightly convex. Individual areas are typically 25 to 35 acres, but a few are about as much as 100 acres in size. This soil has the profile described as representative of the Estherville series. Depth to calcareous sand and gravel is typically 24 to 30 inches.

Included with this soil in mapping are a few areas where the surface layer is sandy loam. Also included are a few areas where sand and gravel is at about 20 inches and other areas where it is slightly more than 30 inches.

Most of the acreage is cultivated. Many areas are used for hay crops and as rotation pasture. This soil is suited to row crops. Crop growth is moderate or poor, especially in years when rainfall is below average or rains are not timely. Soil blowing is often a hazard, because the surface dries quickly after tillage. Blowing sand sometimes damages young plants. Many areas are managed separately, but smaller areas are managed with the adjacent soils. Capability unit IIIs–1, environmental planting group 4.

72B—Estherville loam, 2 to 5 percent slopes. This gently sloping soil is in outwash areas and on stream benches, with Cylinder soils and with other Estherville soils. Small areas are in glacial outwash in the uplands. Slopes are generally short. Individual areas are typically between 5 to 10 acres in size.

This soil has a profile similar to the one described as representative of the series, but the surface layer is slightly thinner. The depth to calcareous sand and gravel is typically 24 to 30 inches. In the uplands the underlying coarse material is not so thick as in out-

wash areas and on benches. A few areas are included where the depth to sand and gravel is about 20 inches.

Most of the acreage is cultivated. Part is in permanent pasture. Crop growth is generally poor to moderate because the available water capacity is low. This soil is moderately suited to row crops, but erosion is a hazard. In most places terracing is not feasible, because it exposes the droughty, coarse-textured underlying material in the terrace channel. Normally this soil is managed with the adjacent soils. Capability unit IIIe-3, environmental planting group 4.

Farrar Series

The Farrar series consists of well drained and somewhat excessively drained sandy soils on the uplands. They formed under prairie grasses in sandy material 18 to 36 inches thick and in the underlying glacial till. They have short irregular slopes, 5 to 9 percent. They are commonly upslope from stream benches.

In a representative profile the surface layer is black and very dark brown fine sandy loam about 14 inches thick. The upper part of the subsoil is dark brown, very dark grayish brown, and brown sandy loam that extends to a depth of about 32 inches. The lower 4 inches of the subsoil is in glacial till and is brown and yellowish brown loam. The substratum is olive gray, dark yellowish brown, and yellowish brown massive loam glacial till.

The Farrar soils have moderate available water capacity. They are moderately rapidly permeable in the upper part and moderately permeable in the substratum. Available nitrogen is low, and available phosphorus and potassium are very low. The sandy material is typically neutral or slightly acid. The loam substratum is typically calcareous, but is frequently neutral in the upper few inches. The organic-matter content is low. These soils warm rapidly in spring and can be worked soon after rains. They erode rapidly because of the slopes. Soil blowing is a hazard if the surface layer is bare or if vegetation is sparse.

Most of the acreage is cultivated because these soils are in small areas adjacent to other soils that are well suited to cultivation. These soils are suited to cultivation, but erosion control is needed. They are generally managed with the adjacent Dickman, Clarion, or Storden soils.

Representative profile of Farrar fine sandy loam, 5 to 9 percent slopes, 630 feet west and 150 feet south of northeast corner sec. 1, T. 96 N., R. 33 W.

Ap—0 to 8 inches, black (10YR 2/1) fine sandy loam; weak, medium, granular structure; very friable; common fine roots; about 5 percent medium sand; slightly acid; abrupt, smooth boundary.

A12—8 to 14 inches, very dark brown (10YR 2/2) fine sandy loam; black (10YR 2/1) coats on faces of peds; weak, medium, granular structure; very friable; common fine roots; about 5 percent medium sand; slightly acid; clear, smooth boundary.

B1—14 to 22 inches, dark-brown (10YR 3/3) and very dark grayish-brown (10YR 3/2) fine sandy loam; common very dark brown (10YR 2/2) coats on faces of peds; some weak, fine, subangular blocky structure parting to weak, medium, granular; very friable; about 10 percent medium sand; neutral; gradual, smooth boundary.

B21—22 to 32 inches, dark-brown (10YR 3/3) and brown (10YR 4/3) sandy loam; weak, medium, subangular blocky structure; very friable; neutral; clear, smooth boundary.

IIB22—32 to 36 inches, brown (10YR 4/3) and yellowish-brown (10YR 5/4) heavy loam; brown (10YR 4/3) coats on faces of peds; weak, medium, subangular blocky structure; friable; common silt coats on faces of peds; neutral; clear, smooth boundary.

IIC1—36 to 45 inches, olive-gray (5Y 5/2) loam; many, fine, prominent, dark-brown (7.5YR 4/4) and few, fine, distinct, dark yellowish-brown (10YR 4/4) mottles; massive; friable; few, fine, strong-brown and black concretions (oxides); neutral; clear, smooth boundary.

IIC2—45 to 60 inches, dark yellowish-brown (10YR 4/4) and yellowish-brown (10YR 5/4) to light olive-brown (2.5YR 5/4) loam; few, fine, distinct, strong-brown (7.5YR 5/8) mottles; massive; friable; few soft calcium carbonate accumulations in soft rounded masses; few strong-brown and black concretions (oxides); slight effervescence; mildly alkaline.

The A horizon is about 10 to 16 inches thick. It is black (10YR 2/1), very dark brown (10YR 2/2), or very dark grayish brown (10YR 3/2).

The B horizon ranges from very dark grayish brown (10YR 3/2) and dark brown (10YR 3/3) in the upper part to brown (10YR 4/3) and yellowish brown (10YR 5/4) in the lower part. The B2 horizon has lenses of loamy fine sand less than 6 inches thick in some places.

The IIB horizon is loam or clay loam that formed in glacial till. The IIC horizon is brown (10YR 4/3), dark yellowish brown (10YR 4/4), yellowish brown (10YR 5/4), light olive brown (2.5Y 5/4), and light yellowish brown (10YR 6/4) loam or clay loam. Mottles of low to high chroma are in some places.

The Farrar soils are on landscapes adjacent to Clarion, Storden, and Dickman soils. They are sandy loam in the upper part of the profile as compared with the Clarion and Storden soils, which are loam. They lack the carbonates that are typical of the Storden soil. In the Dickman soils, the sandy loam and loamy sand extends to a depth of more than 3 feet.

253C—Farrar fine sandy loam, 5 to 9 percent slopes. This moderately sloping soil is in the uplands throughout the county, but it mainly borders high benches. Most areas are small and are adjacent to Clarion or Storden soils. Dickman soils are frequently upslope from this soil.

Included in mapping are some areas where the surface layer is thinner and lighter colored than in the representative profile. In most places it is very dark brown or very dark grayish brown. Also included in mapping are a few areas where the soils are somewhat steeper.

This soil is generally cultivated, but it is subject to soil blowing and water erosion. If erosion is controlled, it is moderately suited to row crops. Crop growth is only moderate in years when rainfall is below average or rains are not timely because of the lack of available water. Soil blowing is often a hazard because the surface dries quickly after tillage. Blowing sand damages young plants.

Planting crops on the contour and terracing help to control erosion and to conserve moisture. Minimum tillage, leaving crop residue on the surface, and spreading strawy manure add organic matter and reduce the hazard of soil blowing. Most areas are not large enough to be managed separately, so they are usually managed with the adjacent soils. Capability unit IIIe-4, environmental planting group 1.

Flagler Variant

The Flagler variant consists of nearly level and gently sloping, somewhat excessively drained soils. These soils are typically on benches along major streams. They formed under prairie grasses in about 2½ to 3 feet of sandy alluvium over calcareous sand and gravel.

In a representative profile the surface layer is very dark brown fine sandy loam about 13 inches thick. The subsoil extends to a depth of about 39 inches. The upper part is very dark grayish brown and brown, friable fine sandy loam and sandy loam. The lower part is dark yellowish brown, friable sandy loam and gravelly sandy loam. The substratum is brown and dark yellowish brown sand and gravel.

These soils have moderate available water capacity. They are moderately rapidly permeable in the upper part and rapidly permeable to very rapidly permeable in the underlying sand and gravel. Available nitrogen and phosphorus are low, and available potassium is very low to low. The soil is typically neutral to slightly acid, but in a few areas it is more acid and needs lime. The organic-matter content is low. These soils are droughty. They warm up rapidly in spring and can be worked soon after rains. They erode rapidly if the surface layer is bare or vegetation is sparse.

Most of the acreage is cultivated. These soils are used for both row crops and forage crops. When used for row crops and prepared for forage seeding, control of soil blowing is needed. Many areas are managed separately, but smaller areas are managed with the adjacent soils.

Representative profile of Flagler sandy loam, calcareous subsoil variant, 0 to 2 percent slopes, on a low stream bench 80 feet south and 250 feet west of northeast corner SW¼ sec. 3, T. 97 N., R. 33 W.

Ap—0 to 7 inches, very dark brown (10YR 2/2) fine sandy loam; black (10YR 2/1) coats on faces of peds; weak, fine, granular structure; very friable; many fine roots; neutral; gradual, smooth boundary.

A12—7 to 13 inches, very dark brown (10YR 2/2) to very dark grayish-brown (10YR 3/2) fine sandy loam; black (10YR 2/1) to very dark brown (10YR 2/2) coats on faces of peds; weak, fine, granular structure; very friable; many fine roots decreasing with increasing depth to common fine roots; neutral; gradual, smooth boundary.

B1—13 to 19 inches, very dark grayish-brown (10YR 3/2) fine sandy loam; very dark brown (10YR 2/2) coats on faces of peds; common, medium, faint, dark yellowish-brown (10YR 4/4) mottles; weak, fine, subangular blocky structure parting to weak, fine, granular; very friable; common fine roots; neutral; gradual, smooth boundary.

B21—19 to 24 inches, brown (10YR 4/3) sandy loam; dark-brown (10YR 3/3) coats on faces of peds; weak, fine and medium, subangular blocky structure parting to weak, fine, granular; very friable; common fine roots; a few very dark grayish-brown (10YR 3/2) coats in old root channels; neutral; gradual, smooth boundary.

B22—24 to 36 inches, dark yellowish-brown (10YR 4/4) sandy loam; dark-brown (10YR 3/3) coats on faces of peds; weak, fine and medium, subangular blocky structure parting to very weak, fine, granular; very friable; common fine roots; neutral; gradual, smooth boundary.

IIB3—36 to 39 inches, dark yellowish-brown (10YR 4/4) gravelly sandy loam; dark-brown (10YR 3/3) coats on faces of peds; very weak, medium, subangular blocky structure parting to single grained; very friable; neutral; gradual, smooth boundary.

IIC—39 to 60 inches, brown (7.5YR 4/4) to dark yellowish-brown (10YR 4/4) sand and gravel; single grained; loose; few stones 1 to 2 inches in diameter; slight effervescence; moderately alkaline.

The A horizon is 8 to 18 inches thick, but in a few places it is thinner because of erosion. The A1 horizon or Ap horizon is black (10YR 2/1) or very dark brown (10YR 2/2). The A12 horizon has colors of the A1 horizon or Ap horizon, but ranges to very dark gray (10YR 3/1) and very dark grayish brown (10YR 3/2).

The B horizon ranges from very dark grayish brown (10YR 3/2) and very dark brown (10YR 3/3) to brown (10YR 4/3) and dark yellowish brown (10YR 4/4). Coats that are one color value lower are common. Similar colors in hue of 7.5YR are in the range. The B horizon is generally free of mottles. It is typically sandy loam, but the IIB3 horizon is typically gravelly sandy loam.

The upper boundary of the IIC horizon, which is at a depth of about 24 to 44 inches, is calcareous sand and gravel.

Flagler soils are neutral to medium acid above the sand and gravel. The sand and gravel is calcareous, but in some places it is neutral in the upper few inches.

The Flagler variant has a profile similar to Dickman soils, but is somewhat finer textured and is underlain by sand and gravel. It is commonly adjacent to Estherville soils, which are shallower over sand and gravel. In texture in the upper horizons it is similar to that of Farrar soils, but lacks the loam or clay loam C horizon.

823—Flagler sandy loam, calcareous subsoil variant, 0 to 2 percent slopes. This nearly level soil is mainly on low benches and in outwash areas. It is commonly adjacent to Dickman, Estherville, or Wadena soils and is above the soils of the bottom lands. This soil has the profile described as representative of the series. Depth to sand and gravel is typically about 36 inches, but it is as shallow as 30 inches and as deep as about 44 inches.

Most of the acreage is cultivated. Row crops are moderately suited to this soil. Crop growth is poor to moderate in most years because of the lack of available water. The surface dries rapidly after tillage. Soil blowing is a hazard. Blowing sand sometimes damages young plants.

Minimum tillage, leaving crop residues on the surface, and spreading strawy manure are ways to add organic matter and reduce the hazard of soil blowing. A few areas are large enough to be managed separately, but most are managed with the adjacent soils. Capability unit IIIs–1, environmental planting group 4.

823B—Flagler sandy loam, calcareous subsoil variant, 2 to 5 percent slopes. This gently sloping soil is mainly on low benches adjacent to the flood plain. It is commonly adjacent to other Flagler soils or Estherville or Wadena soils and is above the soils of the bottoms.

This soil has a profile similar to the one described as representative of the series, but the surface layer is about 10 inches thick. Erosion and plowing have exposed the lighter colored subsoil in places. Depth to calcareous sand and gravel is typically about 30 inches, but ranges from 24 to 40 inches.

Most of the acreage is cultivated, but a few areas are pastured. This soil is subject to both soil blowing and water erosion. It is moderately suited to row crops if erosion is controlled. Because this soil has limited

available water capacity and low fertility, crop growth is poor or moderate, especially in years when rainfall is below average or rains are not timely. The surface layer dries rapidly after tillage. Blowing sand is sometimes a hazard to young plants.

Planting crops on the contour and terracing help to control erosion and conserve moisture. In building terraces, care is needed to avoid exposing the coarse-textured substratum. Minimum tillage, leaving crop residue on the surface, and spreading strawy manure add organic matter and reduce the hazard of soil blowing. A few areas are large enough to be managed separately, but are generally managed with the adjacent soils. Capability unit IIIe–3, environmental planting group 4.

Hanska Series

The Hanska series consists of nearly level, poorly drained soils formed in glacial outwash on valley trains and on stream benches. The native vegetation was marsh grasses, sedges, and prairie grasses that tolerate wetness.

In a representative profile the surface layer is about 17 inches thick. It is black loam in the upper part and dark gray and black sandy loam in the lower part. The subsoil is dark gray and olive gray sandy loam in the upper part and olive and light olive brown sandy loam and gravel in the lower part. It contains yellowish brown, light olive brown, and light olive gray mottles. It is about 15 inches thick. The substratum is mottled light brownish gray, light olive brown, and yellowish brown, calcareous, loose loamy sand and gravel.

The Hanska soils have a low available water capacity. They are moderately rapidly permeable in the upper part and rapidly permeable to very rapidly permeable in the underlying sand and gravel. Available nitrogen is medium or low, available phosphorus is very low, and available potassium is very low. The organic-matter content is high. Typically the surface layer is neutral.

Hanska soils are seasonally wet because of a high water table, and some areas are flooded. In drained areas, these soils are suited to row crops.

Representative profile of Hanska loam, moderately deep, 0 to 2 percent slopes, 45 feet south and 110 feet east of northwest corner NE¼ sec. 11, T. 95 N., R. 33 W.

Ap—0 to 9 inches, black (N 2/0) loam, black (N 2/0) kneaded; moderate, fine, granular and weak, very fine, subangular blocky structure; firm; many, fine clear sand grains throughout the soil mass; neutral; abrupt, smooth boundary.

A12—9 to 13 inches, black (10YR 2/1) and very dark gray (10YR 3/1) loam, black (10YR 2/1) kneaded; few, fine, faint, olive-gray (5YR 4/2) mottles; weak, medium, subangular blocky structure that parts to weak, fine, granular; friable; neutral; clear, wavy boundary.

A3—13 to 17 inches, dark-gray (10YR 3/1) and about 20 percent black (10YR 2/1) heavy sandy loam, same color kneaded; a very few, fine, distinct, light olive-brown (2.5Y 5/4) and yellowish-brown (10YR 5/6) mottles; weak, medium, subangular blocky structure; friable; a few fine strong-brown (7.5YR 5/6) to dark-brown (7.5YR 4/4) concretions (oxides) that are readily crushed; neutral; clear, wavy boundary.

B2g—17 to 25 inches, dark-gray (5Y 4/1) and olive-gray (5Y 4/2) sandy loam; mottles are common fine distinct olive brown (2.5Y 4/4), few fine distinct light olive brown (2.5Y 5/4) and yellowish brown (10YR 5/8), and few fine faint light olive gray (5Y 6/2); weak, medium, subangular blocky structure; friable; a few moderately hard black concretions (oxides); neutral; clear, wavy boundary.

IIB3—25 to 32 inches, olive (5Y 5/3) and light olive-brown (2.5Y 5/4) light sandy loam and gravel; common, fine, distinct, light olive-brown (2.5Y 5/6) and yellowish-brown (10YR 5/8) mottles; very weak, coarse and medium, subangular blocky structure that parts to single grained; very friable; few, 2- to 3-millimeter in diameter, moderately hard, black concretions (oxides); neutral; gradual, wavy boundary.

IIC—32 to 60 inches, mottled light brownish-gray (2.5Y 6/2), light olive-brown (2.5Y 5/4), and yellowish-brown (10YR 5/6 to 5/8) loamy sand and gravel; some strong brown (7.5YR 5/8); single grained loose; slight effervescence; moderately alkaline.

The A horizon is 10 to 22 inches thick. In some places the Ap or A1 horizon is light clay loam or sandy loam.

The B2 horizon ranges from dark gray (5Y 4/1) or gray (5Y 5/1) to grayish brown (2.5Y 5/2) or olive gray (5Y 4/2 or 5/2). The B horizon is typically sandy loam in the upper part and grades to light sandy loam, loamy sand, or loamy sand and gravel in the IIB3 horizon. The depth to calcareous sand and gravel is generally about 24 to 32 inches, but ranges to about 40 inches. Some profiles are leached for a few inches in the upper part of the sand and gravel. Reaction is typically neutral in the solum, but ranges to mildly alkaline.

Hanska soils have profiles similar to those of the adjacent Mayer soils, which are calcareous. The adjacent Linder soils have a browner B horizon. Biscay and Talcot soils, which are on similar landscapes, contain more clay throughout their solum, and the Talcot soils are calcareous in the solum.

150—Hanska loam, moderately deep, 0 to 2 percent slopes. This nearly level soil is in outwash areas and on stream benches, with Linder and Estherville soils. Some areas are adjacent to Biscay and Mayer soils. Individual areas generally range from about 10 to 60 acres in size. The depth to sand and gravel is typically between 24 and 32 inches.

Included with this soil in mapping were areas where the depth to sand is slightly less than 24 inches and other areas where it is about 40 inches. Also included are a few areas where the subsoil is loamy sand and a few areas where the surface layer is sandy loam.

This soil has a seasonal high water table and is poorly drained. Some areas are flooded during periods of high rainfall. Installation of tile drains would improve drainage, but care is needed to avoid over draining this soil. In some places instability of the substratum makes tile installation difficult. Suitable outlets are sometimes not available.

This soil is moderately rapidly permeable above the sand and gravel, and it has a low available water capacity. It is suited to row crops, but lacks sufficient available water, especially when rainfall is below average or rains are not timely. It is subject to soil blowing, especially when plowed in fall. The larger areas are often managed separately, and other areas are managed with the adjacent soils. Capability unit IIw–4, environmental planting group 2.

Harps Series

The Harps series consists of nearly level, poorly drained soils in the uplands. These soils are mainly on convex rims of depressions or potholes of Okoboji soils or Palms muck. A few areas are on flat rises within broad flats of Canisteo soils. Harps soils formed in glacial till and in sediments from glacial till. Slopes are 1 to 3 percent. Native vegetation is marsh grasses, sedges, and prairie grasses that are tolerant of excess wetness.

In a representative profile the surface layer is black loam about 15 inches thick. The subsoil is light clay loam that extends to a depth of about 36 inches. The upper part of the subsoil is black, very dark gray, and dark gray and grades to olive gray, light olive gray, and pale olive. The lower part has yellowish brown and light olive brown mottles. The substratum is light olive gray, friable clay loam that has yellowish brown mottles. These soils are calcareous and high in lime throughout their profile.

The Harps soils have a high available water capacity and are moderately permeable. Available nitrogen is generally low, and available phosphorus and potassium are very low. Available iron is deficient in these soils, and in some places other available minor elements are low. The organic-matter content is high. The plow layer is moderately alkaline.

Harps soils have a high water table and are saturated during parts of the year unless drained. They receive special fertilization because fertility is low. Soil blowing is a hazard if the surface is left bare when plowed in fall. Most of the acreage is tile drained and cultivated. All areas are managed with the adjacent soils. They are too small to be managed as individual fields.

Representative profile of Harps loam, 0 to 2 percent slopes, 1,120 feet east and 300 feet north of southwest corner sec. 2, T. 95 N., R. 32 W., on a 1 percent slope on the east rim of a large depression:

Apca—0 to 8 inches, black (N 2/0) loam, dark gray (N 4/0) dry, black (10YR 2/1) kneaded; weak, fine, granular structure; very friable; common fine roots; violent effervescence; moderately alkaline; abrupt, smooth boundary.

A12ca—8 to 15 inches, black (10YR 2/1) loam, dark gray (N 4/0) dry; few, fine, faint, grayish-brown (2.5Y 5/2) mottles in lower half of horizon; weak, fine, subangular blocky structure parting to weak, medium, granular; friable; common fine roots; violent effervescence; moderately alkaline; gradual, smooth boundary.

B1ca—15 to 21 inches, 50 percent black (10YR 2/1), 30 percent very dark gray (10YR 3/1), and 20 percent dark gray (10YR 4/1) light clay loam, dark gray (N 4/0) and gray (10YR 5/1) dry; common fine faint and few medium faint pale-olive (5Y 6/3) mottles; weak, fine, subangular blocky structure and fine granular; common fine roots; a few 3-millimeter dark-brown (7.5YR 4/4) concretions (oxides); violent effervescence; moderately alkaline; gradual, wavy boundary.

B21gca—21 to 29 inches, pale-olive (5Y 6/3) and olive-gray (5Y 5/2) and 20 percent dark-gray (5Y 4/1) light clay loam, gray (5Y 5/1) kneaded; few, fine, distinct, light olive-brown (2.5Y 5/6) mottles; weak, fine, subangular blocky structure; friable; few fine roots; a few 3-millimeter strong-brown (7.5YR 5/6) concretions (oxides); violent effervescence; moderately alkaline; clear, smooth boundary.

B22g—29 to 36 inches, light olive-gray (5Y 6/2) and 20 percent dark gray (5Y 4/1) clay loam, light olive gray (5Y 6/2) kneaded; common, fine, distinct, yellowish-brown (10YR 5/8) and light olive-brown (2.5Y 5/6) mottles; weak, medium and fine, subangular blocky structure; friable; a few 2-millimeter black and dark-brown (7.5YR 4/4) concretions (oxides); violent effervescence; moderately alkaline; gradual, smooth boundary.

C1g—36 to 48 inches, light olive-gray (5Y 6/2) clay loam; common, fine, distinct, yellowish-brown (10YR 5/8) mottles; massive; friable; a few fine tubular pores; common 1-millimeter strong-brown (7.5YR 5/6) and a few 4-millimeter black concretions (oxides); violent effervescence; moderately alkaline; diffuse, smooth boundary.

C2g—48 to 60 inches, light olive-gray (5Y 6/2) and light-gray (5Y 7/1) clay loam; common, fine, distinct, yellowish-brown (10YR 5/8) and common, fine to medium, strong-brown (7.5YR 5/6) mottles; massive; friable; common 5- to 10-millimeter calcium carbonate accumulations in soft rounded masses; common 1-millimeter strong-brown (7.5YR 5/6) and a few 4-millimeter black concretions (oxides); violent effervescence; moderately alkaline.

The A1 or Ap horizon ranges from loam to light clay loam 10 to 16 inches thick. When moist, it ranges from black (10YR 2/1) to very dark gray (10YR 3/1 or N 3/0). When dry it is dark gray (10YR 4/1 or N 4/0) or gray (10YR 5/1). In some places the A3 horizon is very dark gray (N 3/0 or 10YR 3/1) and almost as much as 40 percent is gray (N 4/0, 10YR 4/1, or 5Y 4/1).

The B horizon ranges from loam and light clay loam to sandy clay loam. The B2 horizon ranges from dark gray (2.5Y 4/1) to gray (5Y 5/1), olive gray (5Y 5/2), light olive gray (5Y 6/2), or pale olive (5Y 6/3). It has few to common yellowish brown and light olive brown mottles. It typically extends to a depth of 30 to 48 inches.

The C horizon is generally loam, but in some places it is light clay loam or sandy clay loam. It is like the B horizon in color. A few small glacial pebbles and excess lime are in all layers.

Harps soils are higher in calcium carbonate and have less clay in the A horizon and in the upper part of the B horizon than Canisteo or Webster soils. They are higher in calcium carbonate and lower in clay than Okoboji soils and are not so dark colored to so great a depth as those soils. All are associated on the landscape.

95—Harps loam, 0 to 2 percent slopes. This nearly level soil is on narrow convex rims that border Okoboji soils and Palms muck. A few areas are on slightly convex slopes in larger areas of Canisteo soils. Most areas are 5 to 10 acres in size, but range to as much as 25 acres.

Included with this soil in mapping were a few acres where very fine sand is below 30 inches. Also included were a few areas of soils, within an area of Talcot soils, that have a sand and gravel substratum.

Most of the acreage is cultivated. This soil is wet unless tilled, and it needs special fertilization when cropped. Available phosphorus is deficient, and available potassium is seriously deficient. Available iron is also seriously deficient, and some minor elements are likely to be in short supply.

If drainage is improved and the fertility deficiencies are corrected, this soil is well suited to row crops. In years of excessive rainfall, crops are lost through water ponding on the adjacent Palms muck and Okoboji soils. Because most areas are small, they are managed with the surrounding Canisteo soils and the adjacent Palms

muck or Okoboji soils. Capability unit IIw–3, environmental planting group 2.

Linder Series

The Linder series consists of nearly level, somewhat poorly drained soils in outwash areas and on stream benches. These soils formed under grasses in alluvium and glacial outwash.

In a representative profile the surface layer is loam about 13 inches thick. It is black in the upper part and grades to mixed very dark brown and very dark gray. The subsoil is about 11 inches thick. It is dark grayish brown to olive brown and dark yellowish brown, friable sandy loam mottled with olive brown and yellowish brown. The substratum is olive brown, light olive brown, dark yellowish brown, and yellowish brown, loose, calcareous sand and gravel.

These soils have a low available water capacity. Above the sand and gravel these soils are moderately rapidly permeable, but in the sand and gravel they are rapidly permeable to very rapidly permeable. In some places in spring, the seasonal water table is within 2 feet of the surface and the soil is wet. By midsummer crops lack enough available water unless rains are timely. These soils generally are not tile drained. Available nitrogen is low, and available phosphorus and potassium are very low. The organic-matter content is moderate. The surface layer is typically neutral, but in places it is slightly acid.

Most of the acreage is cultivated. Linder soils are sometimes managed separately, but are generally managed with the adjacent soils.

Representative profile of Linder loam, 0 to 2 percent slopes, 60 feet east and 190 feet south of the northwest corner of NE¼ sec. 29, T. 96 N., R. 31 W.

Ap—0 to 7 inches, black (10YR 2/1) heavy loam; moderate, fine and medium, granular structure; friable; many roots; common fine clear sand grains on ped surfaces; neutral; clear, smooth boundary.

A3—7 to 13 inches, mixed black (10YR 2/1), very dark brown (10YR 2/2), and very dark gray (10YR 3/1) light loam, very dark gray (10YR 3/1) kneaded; weak, fine to medium, subangular blocky structure parting to moderate, fine and medium, granular; friable; a few very dark grayish-brown (10YR 3/2) peds; some light olive-brown (2.5Y 5/4) worm mixing in lower part; mildly alkaline; clear, smooth boundary.

B21—13 to 20 inches, dark grayish-brown (2.5Y 4/2) to olive-brown (2.5Y 4/3) sandy loam, dark grayish brown (2.5Y 4/2) kneaded; dark grayish-brown (2.5Y 4/2) coatings on faces of peds; weak, fine and medium, subangular blocky structure parting to moderate, fine and medium, granular; friable; some light olive-brown (2.5Y 5/4 to 5/6) worm mixing; mildly alkaline; gradual, wavy boundary.

B22—20 to 24 inches, olive-brown (2.5Y 4/3) and dark yellowish-brown (10YR 4/4) sandy loam; few dark grayish-brown (2.5Y 4/2) coatings on faces of peds; common, fine, faint, yellowish-brown (10YR 5/6 to 5/8) mottles; weak, fine and medium, subangular blocky structure parting to weak, fine and medium, granular; friable; few coarse to very coarse sand grains and fine pebbles coated with clay; mildly alkaline; gradual, wavy boundary.

IIC1—24 to 28 inches, mixed dark yellowish-brown (10YR 4/4) and yellowish-brown (10YR 5/6) gravelly loamy sand; single grained; loose; few calcium carbonate accumulations in fine soft rounded masses; clay bridging between most sand grains; strong effervescence; moderately alkaline; gradual, wavy boundary.

IIC2—28 to 60 inches, light olive-brown (2.5Y 5/4), dark yellowish-brown (10YR 4/4), and yellowish-brown (10YR 5/4) sand and gravel; single grained; loose; strong effervescence; moderately alkaline.

The A horizon is 10 to 20 inches thick. The Ap or A1 horizon is black (10YR 2/1 or N 2/0) or very dark brown (10YR 2/2). The A3 horizon is very dark grayish-brown (10YR or 2.5Y 3/2), very dark brown (10YR 2/2), or very dark gray (10YR 3/1) loam or sandy loam.

The B horizon is typically dark grayish brown (2.5Y 4/2), olive brown (2.5Y 4/3), or grayish brown (2.5Y 5/2). It ranges to very dark grayish brown (10YR 3/2 to 2.5Y 3/2) in the upper part and dark brown (10YR 4/3) and dark yellowish brown (10YR 4/4) in the lower part. Yellowish-brown or light olive-brown mottles are common. The B horizon is dominantly sandy loam, but in some places the lower few inches of the B2 horizon is loamy sand. In some places the soil has a B3 horizon of loamy sand or sand and gravel. The A and B horizons are typically slightly acid to mildly alkaline. The A horizon is medium acid in some places.

Depth to the underlying sand and gravel is typically 24 to 30 inches, but ranges from 18 to 36 inches. This material is 3 to many feet thick. It is calcareous except for being leached for a few inches in the upper part in many places.

Linder soils have more sand and less clay in the upper parts of their profile than the similar Cylinder soils. They have a grayer B horizon than the adjacent Estherville soils. The associated Hanska soils have a grayer B horizon and are more poorly drained.

224—Linder loam, 0 to 2 percent slopes. This nearly level soil is in outwash areas and on stream benches. It is associated with Cylinder, Wadena, Estherville, and Biscay soils. The slopes range from slightly convex to slightly concave. A few areas are large, but most areas are only 5 to 20 acres in size. Included in mapping is about 160 acres of similar soils that are calcareous throughout.

Most of the acreage is cultivated and used for row crops. These soils are sometimes wet in spring, but by midsummer crops lack enough available water unless rains are timely and above average in amount. Crop growth varies, but is generally only moderate. If the soil is plowed in fall, soil blowing is a hazard. Most areas are managed with the adjacent soils. Capability unit IIs–1, environmental planting group 4.

Marsh

Marsh (354) is covered with water most of the time. Because it is flooded most of the time, the soil material has not been examined in great detail. It has variable texture. In Palo Alto County, marsh is in depressions and adjacent to lakes. The vegetation is cattails, lilies, and other marsh plants. Marsh has no value for farming, but it is an important habitat for waterfowl, muskrats, and other wetland wildlife.

Included in mapping and identified on the soil map by spot symbols are wet seepy areas in the uplands. These areas are frequently on hillsides. Some occur as conical shaped mounds in gently undulating or gently rolling topography.

Most areas of Marsh are in the western part of the county. Several areas that are made up largely of

Marsh have been designated as game refuges and public shooting grounds. These areas include the Blue Wing Marsh, Oppedal Areas, and Fallow Marsh in Lost Island Township and the Rush Lake State Park in Booth Township. Capability unit VIIw–1, environmental planting group 2.

Mayer Series

The Mayer series consists of poorly drained, nearly level soils that are calcareous throughout their profile. These soils are in outwash areas, on stream benches, and in valley trains throughout the county. Slopes are 1 to 3 percent. The native vegetation is marsh grasses, sedges, and prairie grasses that tolerate wetness.

In a representative profile the surface layer is black loam about 16 inches thick. The subsoil is dark gray, gray, or olive gray, friable loam. It has olive brown mottles. Beginning at a depth of about 30 inches the substratum is mottled olive gray and yellowish brown calcareous sand and gravel.

Mayer soils have a moderate available water capacity. Permeability is moderate to moderately rapid in the upper part and rapid or very rapid in the underlying sand and gravel. These soils are moderately alkaline throughout the profile. Available nitrogen is medium or low, and available phosphorus and potassium are very low. Available iron is low in places. The organic-matter content is high.

Mayer soils are wet because of a high water table. Where drained, they are well suited to row crops. Larger areas are sometimes managed separately, but most are managed with the adjacent soils.

Representative profile of Mayer loam, moderately deep, 0 to 2 percent slopes, 675 feet east and 132 feet south of the northwest corner of NE¼ sec. 13, T. 94 N., R. 33 W.

Ap—0 to 7 inches, black (N 2/0) loam; moderate, fine, granular structure and weak, fine, subangular blocky; friable; common fine roots; strong effervescence; moderately alkaline; abrupt, smooth boundary.

A12—7 to 12 inches, black (N 2/0) loam; few very dark gray (N 3/0) peds; moderate, fine, granular structure and weak, fine, subangular blocky; friable; common fine roots; strong effervescence; moderately alkaline; gradual, smooth boundary.

A3—12 to 16 inches, black (N 2/0) and very dark gray (10YR 3/1) loam grading to black (10YR 2/1) and dark grayish brown (2.5Y 4/2) in lower part; few, fine, faint, grayish-brown (2.5Y 5/2) mottles; moderate, fine, granular structure and weak, fine, subangular blocky; friable; common fine roots; strong effervescence; moderately alkaline; gradual, smooth boundary.

B1g—16 to 21 inches, gray (5Y 5/1) and dark-gray (5Y 4/1) loam, 20 percent very dark gray (5Y 3/1) in upper part; weak, fine, subangular blocky structure; friable; few fine roots; strong effervescence; moderately alkaline; gradual, smooth boundary.

B21g—21 to 25 inches, olive-gray (5Y 5/2) and dark-gray (5Y 4/1) loam grading to mostly olive gray (5Y 5/2) in lower part; weak, fine, subangular blocky structure; friable; few fine roots; few fine calcium carbonate accumulations in soft rounded masses; strong effervescence; moderately alkaline; clear, smooth boundary.

B22g—25 to 30 inches, olive-gray (5Y 5/2) loam; few dark-gray (5Y 4/1) peds; few, fine, distinct, light olive-brown (2.5Y 5/6) mottles; weak, medium, subangular blocky structure; friable; a few fine roots; few medium calcium carbonate accumulations in soft rounded masses; a few fine black and strong-brown concretions (oxides); strong effervescence; moderately alkaline; clear, wavy boundary.

IIC1—30 to 44 inches, mixed olive-gray (5Y 5/2), yellowish-brown (10YR 5/4), and dark yellowish-brown (10YR 4/4) sand and gravel; single grained; loose; few 4- to 5-millimeter black oxide and few fine strong-brown concretions (oxides); violent effervescence; moderately alkaline; diffuse, wavy boundary.

IIC2—44 to 60 inches, yellowish-brown (10YR 5/6) sand and gravel; single grained; loose; common, fine, strong-brown concretions (oxides); violent effervescence; moderately alkaline.

The A horizon is about 14 to 24 inches thick. It typically ranges from black (N 2/0 or 10YR 2/1) in the upper part to very dark gray (10YR 3/1 or N 3/0) in the lower part. It is typically heavy loam, but in some places it is sandy clay loam.

The B horizon ranges from dark gray (5Y 4/1) to olive gray (5Y 5/2). In the upper part are coatings and peds of very dark gray. It is typically heavy loam, but it ranges to sandy clay loam or sandy loam that has some gravel in the lower part.

The C horizon is mixed calcareous sand and gravel. It is generally at a depth of 24 to 30 inches, but the depth ranges from 20 to 36 inches.

Mayer soils are calcareous throughout their profile, unlike the Biscay soils. They resemble Canisteo soils, except for the underlying sand and gravel. Mayer soils contain less lime than Harps soils, which do not overlie sand and gravel. They are similar to Talcot soils, but contain less clay. All are poorly drained.

658—Mayer loam, moderately deep, 0 to 2 percent slopes. This nearly level soil is in outwash areas and on stream benches. It is associated with Talcot, Biscay, Hanska, and Wadena soils. Individual areas range from 5 to about 60 acres in size. This soil has the profile described as representative of the series.

Included with this soil in mapping and identified on the soil map by spot symbols are a few areas of one-half acre or less of Okoboji soils. Also included are a few areas of strongly calcareous soils that have a dark-gray surface layer when dry. In these areas available phosphorus and potassium are likely to be very low, and available iron and other minor elements generally are deficient.

This soil is poorly drained, and some areas are flooded during periods of high rainfall. Drainage can be improved by tile drains, but care is needed to avoid overdraining this soil. In some places instability of the substratum makes installation of the tile drains difficult.

This soil is well suited to row crops, but crops lack enough available water when rainfall is below average or rains are not timely. This soil is subject to soil blowing when plowed in fall unless the surface is protected. Large areas sometimes are managed separately, but most areas are managed with the adjacent soils. Capability unit IIw–5, environmental planting group 3.

895—Mayer loam, sandy loam subsoil, 0 to 2 percent slopes. This nearly level soil is in outwash areas and on stream benches, with Hanska, Linder, and Estherville soils. Some areas are adjacent to Biscay and Talcot soils. Individual areas are generally 10 to 60 acres in size. The depth to sand and gravel is typically between 24 and 38 inches; it averages about 30 inches.

Included with this soil in mapping are areas where the depth to sand and gravel is slightly less than 24 inches. Also included are a few areas where the subsoil is loamy sand and areas where the surface layer is sandy loam.

This soil has a seasonal high water table and is poorly drained. Some areas are flooded during periods of high rainfall. Drainage can be improved by tile drains, but care is needed to avoid overdraining the soil. In some places instability of the substratum makes installation of tile drains difficult. Suitable outlets are sometimes not available. The soil is moderately permeable to moderately rapidly permeable above the sand and gravel. It has a lower available water capacity than other Mayer soils.

This soil is suited to row crops but is subject to soil blowing, especially when it is plowed in fall. Crops may lack enough available water when rainfall is below average or rains are not timely. The larger areas of this soil are often managed separately, and other areas are managed with the adjacent soils. Capability unit IIw–4, environmental planting group 3.

Nicollet Series

The Nicollet series consists of somewhat poorly drained soils on uplands. These soils formed in glacial till under native vegetation of prairie grasses. Slopes are either convex or concave and are 1 to 3 percent.

In a representative profile the surface layer is black heavy loam about 19 inches thick. The subsoil extends to a depth of about 39 inches. It is dark grayish brown light clay loam that is mottled in the lower part. The substratum is grayish brown, light brownish gray, and yellowish brown loam.

Nicollet soils have a high available water capacity and are moderately permeable. They have a water table at a depth of 2 to 4 feet during wet seasons. Available nitrogen is low to medium, available phosphorus is very low to low, and available potassium is very low to low. The organic-matter content is high. The surface layer is neutral to slightly acid.

These soils are wet during periods of high rainfall, but wetness does not limit crop growth. Many areas are artificially drained to improve timeliness of fieldwork. Almost all the acreage is cultivated. Soil blowing is a hazard if these soils are plowed in fall and left bare. Most areas are irregular in shape and size and are managed with the associated soils.

Representative profile of Nicollet loam, 1 to 3 percent slopes, 676 feet east and 327 feet north of southwest corner SE¼ sec. 33, T. 95 N., R. 33 W., in a broad area of 2 percent slope.

Ap—0 to 7 inches, black (N 2/0) heavy loam; cloddy parting to moderate, fine, granular structure; friable; many fine roots; few fine pebbles and sand grains; slightly acid; abrupt, smooth boundary.

A12—7 to 13 inches, black (10YR 2/1) heavy loam; moderate, fine, granular structure; friable; common fine roots; few fine pebbles and sand grains; slightly acid; gradual, smooth boundary.

A3—13 to 19 inches, black (10YR 2/1) heavy loam, 20 percent dark grayish brown (10YR 4/2) in lower part; weak, fine, subangular blocky structure parting to moderate, fine, granular; friable; common fine roots; few fine pebbles and sand grains; neutral; gradual, smooth boundary.

B1—19 to 25 inches, mixed very dark gray (10YR 3/1) and dark grayish-brown (10YR 4/2) light clay loam, dark grayish brown (10YR 4/2) kneaded; some black (10YR 2/1) peds decreasing in number with increasing depth; weak, fine, subangular blocky structure parting to moderate, fine, granular; friable; few fine roots; few fine pebbles and sand grains; few, fine, hard, black concretions (oxides); neutral; gradual, smooth boundary.

B21—25 to 31 inches, dark grayish-brown (2.5Y 4/2) light clay loam, dark grayish brown (2.5Y 4/2) kneaded; few light olive-brown (2.5Y 5/4) peds; few very dark gray (10YR 3/1) coats on faces of peds in upper part; weak, fine and medium, subangular blocky structure; friable; few fine black concretions (oxides) that are readily crushed; few fine roots; neutral; gradual, smooth boundary.

B22—31 to 39 inches, dark grayish-brown (2.5Y 4/2) and some grayish brown (2.5Y 5/2)) light clay loam, light olive brown (2.5Y 5/4) kneaded; few, fine, distinct, yellowish-brown (10YR 5/6) mottles; weak, fine and medium, subangular blocky structure; friable; few fine black concretions (oxides); few very fine strong-brown concretions (oxides) that are readily crushed; a few fine calcium carbonate accumulations in soft rounded masses in the lower half of the horizon; few fine roots; mildly alkaline; gradual, smooth boundary.

C1—39 to 48 inches, grayish-brown (2.5Y 5/2) and light brownish-gray (2.5Y 6/2) heavy loam, olive (5Y 5/3) kneaded; common, fine, distinct, yellowish-brown (10YR 5/6) mottles; massive; friable; common fine to medium calcium carbonate accumulations in soft rounded masses; few fine black concretions (oxides); few fine strong-brown concretions (oxides) that are readily crushed; strong effervescence; moderately alkaline; gradual, smooth boundary.

C2—48 to 60 inches, mixed yellowish-brown (10YR 5/4 and 5/6) and light brownish-gray (10YR 6/2) heavy loam; friable; common fine and medium calcium carbonate accumulations in soft rounded masses; few fine black concretions (oxides); few fine strong-brown concretions (oxides) that are readily crushed; violent effervescence; moderately alkaline.

The A horizon is black (10YR 2/1 to N 2/0), very dark brown (10YR 2/2), very dark gray (10YR 3/1), and very dark grayish brown (10YR 3/2). It is 14 to 22 inches thick.

The light clay loam or loam B horizon has ped interiors of dark grayish brown (10YR 4/2 or 2.5Y 4/2) in the upper part. The lower part of the B horizon has hue of 2.5Y, value of 4 or 5, and chroma of 2 to 4.

The C horizon is grayish brown (2.5Y 5/2) to light olive brown (2.5Y 5/4), yellowish brown (10YR 5/4 to 10YR 5/6) or light brownish gray (2.5Y 6/2 or 10YR 6/2), and olive gray (5Y 5/2) to olive (5Y 5/4).

Few to common, prominent or distinct mottles are in the lower part of the B horizon and in the C horizon. In many places matrix colors are mixed. Nicollet soils are slightly acid to neutral in the upper part of the B horizon. The lower part and the C horizon are neutral to mildly alkaline or moderately alkaline. Carbonates are at depths between 24 and 40 inches in most places, but the depth ranges from 20 to 48 inches. In some places the thickness of solum and depth to carbonates are the same, but in other places the solum extends into the calcareous material. In some places there are pockets or thin lenses of sandy material.

Nicollet soils have a thicker A horizon than the well drained Clarion soils and a mottled B horizon that the Clarion soils lack. They are not so gray in the B horizon as the poorly drained Webster soils. They lack the sand and gravel C horizon that is typical of Cylinder soils. Nicollet soils are associated with all but Cylinder soils. Nicollet and Cylinder soils have similar drainage.

55—Nicollet loam, 1 to 3 percent slopes. This nearly level soil has mainly slightly convex slopes that are

generally short. In a few areas in the eastern part of the county, slopes are longer and smooth. This soil is below Clarion soils and about Webster or Canisteo soils. A few areas are in concave positions between undulating areas of Clarion or Storden soils. Areas of this soil range from 5 to 100 acres or more in size. In Silver Lake, Highland, Lost Island, and Walnut Townships, the average area of this soil is small and is more often in swales than in other parts of the county.

Included with this soil in mapping were small areas of soils similar to Clarion soils. Also included and identified by spot symbols on the soil map are areas of one-half acre or less of wet soils, areas of one-half acre or less of Okoboji soils, and a few areas of one-half acre or less of Rolfe soils.

Most of the water that falls on the surface is absorbed. In places on a few longer slopes, slight erosion occurs. Soil blowing is more of a hazard if large tracts are plowed in fall. In years of above average rainfall, the soil is wet where it borders Webster soils. Tile drainage improves the timeliness of fieldwork.

This soil is well suited to row crops. Good management and adequate fertilization maintain good soil tilth and excellent crop growth. A few large areas are managed separately, but most areas are managed with Webster, Canisteo, and Clarion soils. Capability unit I–1, environmental planting group 1.

Okoboji Series

The Okoboji series consists of very poorly drained, nearly level soils in depressions. These soils formed under native marsh grasses and sedges in local alluvium washed from adjacent soils. They are in depressions in the uplands throughout the county.

In a representative profile the surface layer is black, firm silty clay loam about 32 inches thick. The subsoil is about 25 inches thick. It is very dark gray in the upper part and grades to gray in the lower part. The lower part has light olive-brown, dark yellowish brown, and yellowish brown mottles. The texture is heavy silty clay loam in the upper part and medium silty clay loam in the lower part. The substratum is gray and dark gray, massive clay loam. It has dark brown to brown and strong brown mottles.

Okoboji soils have a high available water capacity and are moderately slowly permeable. These soils have a high water table unless artificially drained. They are ponded with runoff from surrounding soils for short periods after rains. The surface layer puddles easily if worked wet. Available nitrogen is medium or low, available phosphorus is very low, and available potassium is very low to low. The organic-matter content is high. The surface layer is neutral to moderately alkaline.

Most of the acreage is drained and cultivated. A few areas are pastured. A few undrained areas are suitable for development as wildlife habitat. Okoboji soils are managed with the associated soils.

Representative profile of Okoboji silty clay loam, 0 to 1 percent slopes, 186 feet north and 36 feet east of southwest corner SW¼NW¼ sec. 21, T. 97 N., R. 32 W.

Ap—0 to 8 inches, black (N 2/0) heavy silty clay loam, same color kneaded; very few, fine, faint, very dark brown (10YR 2/2) mottles in lower part; cloddy parting to moderate, fine and very fine, granular structure; firm; common fine roots; mildly alkaline; abrupt, smooth boundary.

A12—8 to 16 inches, black (N 2/0) heavy silty clay loam, same color kneaded; very few, fine, faint, very dark brown (10YR 2/2) mottles; moderate, fine, granular and very fine, subangular blocky structure; firm; common fine roots; mildly alkaline; gradual, smooth boundary.

A13—16 to 24 inches, black (N 2/0) heavy silty clay loam, same color kneaded; moderate, very fine, subangular blocky and fine, granular structure; firm; few fine tubular pores; mildly alkaline; gradual, smooth boundary.

A3—24 to 32 inches, black (N 2/0) to very dark gray (N 3/0) heavy silty clay loam, same color kneaded; very few, fine, distinct, light olive-brown (2.5Y 5/4) mottles; weak, fine, prismatic structure parting to moderate, fine and very fine, subangular blocky tending to angular blocky; firm; a few fine roots and a few tubular pores; very few, fine, brown (7.5YR 4/4) concretions (oxides); mildly alkaline; gradual, smooth boundary.

B1—32 to 42 inches, very dark gray (N 3/0) heavy silty clay loam, same color kneaded; few, fine, faint, very dark grayish-brown (2.5Y 3/2) mottles; weak, medium, prismatic structure parting to weak, fine, subangular blocky; firm; few fine tubular pores; very few fine strong-brown (7.5YR 4/4) concretions (oxides); mildly alkaline; clear, smooth boundary.

B2g—42 to 48 inches, mixed very dark gray (5Y 3/1) and dark-gray (5Y 4/1) medium silty clay loam; few fine faint gray (5Y 5/1) to light-gray (5Y 6/1) and olive (5Y 5/3) mottles; weak, medium, prismatic structure parting to weak, fine, subangular blocky; firm; common fine tubular pores; few old root pores with fills darker than very dark gray (5Y 3/1); common calcium carbonate accumulations in soft rounded masses about 2 millimeters in diameter; mildly alkaline; clear, smooth boundary.

B3g—48 to 57 inches, gray to light-gray (5Y 5/1 to 6/1) medium silty clay loam, same color kneaded; common, fine, prominent, light olive-brown (2.5Y 5/4) mottles; many, medium, prominent, dark yellowish-brown (10YR 3/4 to 4/4) to yellowish-brown (10YR 5/6) mottles between 52 and 56 inches; weak, medium, prismatic structure; firm; few fine calcium carbonate accumulations in soft rounded masses 2 to 3 millimeters in diameter; very dark gray (N 3/0) clay fills in old root channels; few fine tubular pores; mildly alkaline; diffuse, smooth boundary.

Cgca—57 to 69 inches, gray (5Y 5/1) and 25 percent dark-gray (5Y 4/1) clay loam, olive gray (5Y 5/2) kneaded; common, fine, faint, light olive-gray (5Y 6/2) and common, fine, prominent, brown (7.5YR 4/4) to strong-brown (7.5YR 5/6) mottles; massive; firm; very dark gray (N 3/0) clay fills in old root channels; few fine tubular pores; few calcium carbonate accumulations in soft rounded masses 2 to 3 millimeters in diameter; strong effervescence; moderately alkaline.

The A horizon ranges from about 24 to 36 inches in thickness. It is typically heavy silty clay loam, but ranges from heavy silt loam to heavy silty clay loam. In some places the A1 horizon is mucky silt loam. The A horizon is typically black (N 2/0 or 10YR 2/1), but in some places is very dark gray (N 3/0).

The B horizon is typically 18 to 24 inches thick, but ranges from about 15 to 30 inches thick. It is very dark gray (10YR 3/1, 2.5Y 3/1, or 5Y 3/1), dark gray (2.5Y 4/0 or 5Y 4/1), gray (5Y 5/1), or olive gray (5Y 5/2). Olive to gray and dark yellowish-brown or yellowish-brown mottles are typical.

The C horizon is generally dark gray (5Y 4/1), gray

(5Y 5/1), or olive gray (5Y 5/2) with mottles like those in the B horizon. It ranges from light clay loam to heavy silty clay loam, but in some places there are layers of loam, silt loam, or silty clay loam, high in content of sand.

The Okoboji soils on benches are outside the range of the series, because they have a higher content of sand than the range of the series allows. The A and B horizons are neutral to mildly alkaline. The solum ranges from about 40 to 60 inches thick.

Okoboji soils are similar to Colo soils, but are mainly in upland depressions, have somewhat more clay, and are generally shallower over gleyed layers. They have a thicker A horizon and they are lower in sand content than Webster soils. They have a thicker, darker A horizon than Rolfe soils and lack the gray A2 horizon that is characteristic of those soils. Okoboji and Rolfe soils are in depressions. Okoboji soils are associated on the landscape with Webster soils.

6—Okoboji silty clay loam, 0 to 1 percent slopes. This nearly level soil is in distinct concave depressions in the uplands (fig. 17). It is generally adjacent to Canisteo soils, and in many areas is surrounded by strips of Harps soils. Many areas are adjacent to Webster soils. A few are adjacent to Nicollet and Clarion soils. Areas range from 5 to 20 acres in size.

This soil has the profile described as representative of the series. In the larger depressions, the surface layer contains more organic matter and is generally more friable and more easily tilled than in the smaller areas of about 5 acres or less. The smaller areas generally have more sand in the surface layer.

Included with this soil in mapping were a few areas of soils that are calcareous in the surface layer and others that are calcareous throughout the profile. Also included are a few areas where the dark surface layer is only about 30 inches thick.

This soil is naturally very poorly drained, and many areas are ponded in spring and after heavy rains. Artificial drainage is needed. Surface intakes and shallow ditches are used in addition to tile drains. In many places it is difficult to find outlets deep enough for tile drains to drain adequately.

Most of the acreage is artificially drained, or partly drained and cultivated. Crop growth is variable. Row crops are moderately suited if drainage is adequate. In some years water is ponded long enough to drown out crops. If this occurs early in the season, the land is tilled and replanted. Even where artificial drainage is adequate for good crop growth, tillage is delayed after heavy rains. The surface layer puddles easily if worked when wet.

A few undrained areas are used for permanent pasture. Some areas are suitable for development as

Figure 17.—Small depression, or pothole, in Okoboji silty clay loam, 0 to 1 percent slopes. This soil is frequently ponded after rains, and crops are often killed or damaged.

wildlife habitat (fig. 18). This soil is generally managed with the adjacent soils. Capability unit IIIw–1, environmental planting group 2.

90—Okoboji mucky silt loam, 0 to 1 percent slopes. This nearly level soil is in distinctly concave depressions in the uplands. Most areas are surrounded by narrow bands of Harps soils, and those areas are adjacent to areas of Canisteo soils. This soil is also adjacent to Clarion and Nicollet soils, especially in Highland, Lost Island, and Walnut Townships. Areas of these soils are usually larger and more circular in shape than other areas of Okoboji soils; many are 20 acres or more, and a few areas are about 80 acres.

This soil is similar to the one described as representative of the series, but the surface layer is mucky silt loam 12 to 18 inches thick and the subsoil is generally black silty clay loam. The surface layer has higher organic-matter content and is less dense and compacted than other Okoboji soils. Less power is needed to work the soil, and preparing a desirable seedbed is easier.

Included with this soil in mapping are a few areas where a gray substratum is at a depth of about 24 inches. Also included are areas of soils that are calcareous in the surface layer and of soils that are calcareous throughout. These soils are in somewhat deeper depressions than other areas of Okoboji soils, and they are ponded for longer periods.

This soil is naturally very poorly drained, and many areas are ponded in spring and after heavy rains. Artificial drainage is needed. Surface intakes and shallow ditches are used in addition to tile drains. In many places it is difficult to find outlets deep enough for tile drains to drain adequately.

Most of the acreage is artificially drained, or partly drained and cultivated. Crop growth is good, and row crops are moderately suited. In some years crops are ponded and drowned out. If this occurs early enough in the season, the land is tilled and replanted. Even where artificial drainage is adequate for good row crop growth, tillage is delayed after heavy rains. Legumes are susceptible to winterkill and are ponded and drowned out early in spring and after heavy rains.

Some partially drained areas of this soil are used for pasture. Undrained areas are suitable as wildlife habitat. Capability unit IIIw–2, environmental planting group 2.

T6—Okoboji silty clay loam, benches, 0 to 1 percent slopes. This nearly level soil is in slightly concave depressions that are surrounded in most places by the

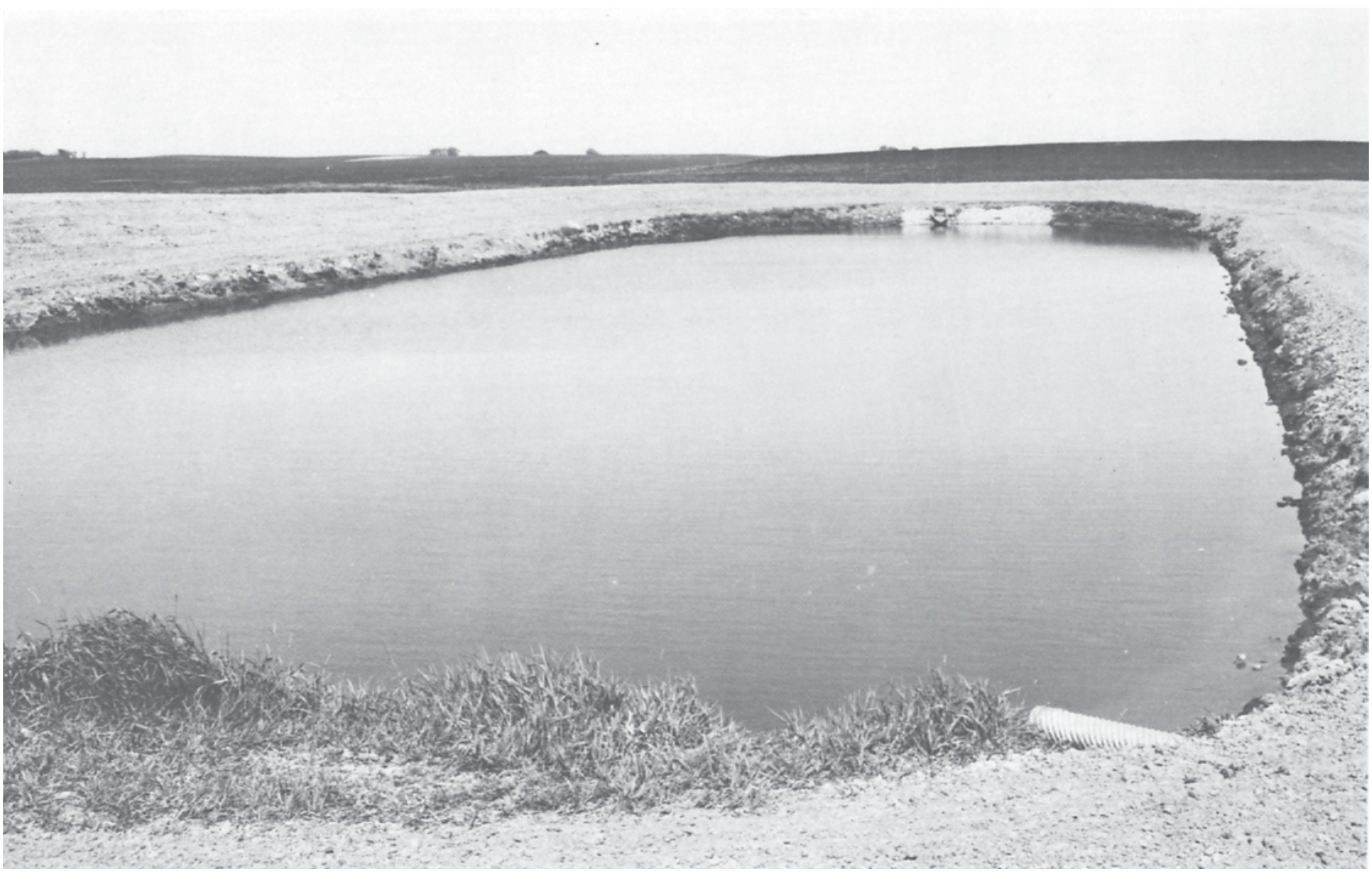

Figure 18.—**Pitpond, or dugout pond, in undrained area of Okoboji silty clay loam, 0 to 1 percent slopes. This pond is now valuable for wildlife and recreation; it replaces land of little agricultural value.**

calcareous Talcot soils or by Biscay soils. Areas are about 5 acres in size.

This soil is similar to the one described as representative of the series, but it has more sand throughout the profile and is generally only 36 to 46 inches deep over mixed sand and gravel or sand, and in a few places, only about 30 inches deep.

Included with this soil in mapping were areas where the surface layer is clay loam. Also included were a few areas of soils that are calcareous in the surface layer and throughout the profile. Some areas that are one-half acre or less are identified by spot symbols on the soil map.

This soil is naturally very poorly drained, and many areas are ponded in spring and after heavy rains. Artificial drainage is needed. Shallow ditches are used in addition to the tile drains. Adequate outlets for tile drains are often not available. In places installation of tile drains is difficult because of gravelly or sandy substratum. Most of the acreage is artificially drained, or partly drained and cultivated. Crop growth is variable. If drainage is adequate, this soil is moderately suited to row crops.

A seasonal high water table and ponding sometimes damage crops, even if artificial drainage is installed. Standing water and the high water table often delay tillage, especially during periods of above normal rainfall. This soil is generally managed with the adjacent soils. Capability unit IIIw-1, environmental planting group 2.

Palms Series

Palms muck consists of very poorly drained, nearly level organic soils. These soils are in old dry lakebeds or in drained depressions. A few seepy areas are along small meandering streams. The native vegetation was marsh grasses and sedges.

In a representative profile the upper 30 inches is black, friable muck and mucky silt loam. Below this is friable, mainly black silty clay loam.

Palms muck has a very high available water capacity. It is moderately permeable in the upper part and moderately permeable to slowly permeable in the lower part. Available nitrogen is generally high, available phosphorus is low, and available potassium is very low. In some places trace elements are deficient for some crops. The soil is neutral to mildly alkaline. It is slow to warm in spring, which often delays planting. Frost often injures crops late in spring and early in fall because the areas are low. Palms muck has a high water table unless artificially drained. Runoff from surrounding slopes ponds on these areas during a heavy rainfall.

Some areas are drained and cultivated. Others are undrained and remain in native swamp grasses and sedges. Where drained and well managed these soils are suited to cultivation. They are subject to soil blowing if the surface is left bare after plowing. Most undrained areas are suitable for development as wildlife habitat.

Representative profile of Palms muck, 0 to 1 percent slopes, 300 feet west and 40 feet south of northeast corner NW¼ sec. 34, T. 97 N., R. 34 W.

Oa1—0 to 7 inches, black (N 2/0) muck (sapric material); moderate, fine, granular structure; very friable; many, fine and medium, densely matted roots; neutral; gradual, smooth boundary.

Oa2—7 to 13 inches, black (N 2/0) muck (sapric material); moderate, fine, granular structure; very friable; many fine roots; neutral; gradual, smooth boundary.

Oa3—13 to 18 inches, black (N 2/0) muck (sapric material); massive; very friable; many fine roots; common snail particles of dark-brown (7.5YR 3/2), partially decayed plant tissue; neutral; clear, smooth boundary.

Oa4—18 to 24 inches, black (N 2/0) muck (sapric material); massive; friable (slightly compacted); a few fine roots; common dark-brown to brown (7.5YR 3/2 to 4/4) fills in old root pores; a few particles of dark-brown (7.5YR 3/2), partially decayed plant tissue; neutral; clear, wavy boundary.

Oa5—24 to 30 inches, black (10YR 2/1), very dark gray (5Y 3/1), and grayish-brown (2.5Y 5/2) mucky silt loam; common, fine, faint, light olive-brown (2.5Y 5/4) mottles; massive; friable; few fine roots; reddish-brown (5YR 4/4) fills in old root pores; few snail shell fragments; slight effervescence; mildly alkaline; clear, wavy boundary.

C1—30 to 37 inches, black (N 2/0) light silty clay loam; massive; friable; few fine roots; reddish-brown (5YR 4/4) fills in old root pores; slight effervescence; mildly alkaline; clear, wavy boundary.

C2—37 to 42 inches, black (10YR 2/1), very dark gray (5Y 3/1), and light olive-brown (2.5Y 5/4) light silty clay loam; common, fine, faint, olive-yellow (2.5Y 6/6) mottles; massive; friable; few fine roots; common snail shell fragments; reddish-brown (5YR 4/4) and yellowish-red (5YR 4/6) fills in old root pores; slight effervescence; moderately alkaline; clear, smooth boundary.

C3—42 to 60 inches, black (N 2/0) light silty clay loam; friable; yellowish-red (5YR 4/6) fills in old root pores; few snail shell fragments; slight effervescence; mildly alkaline.

The organic layer in Palms muck is generally 20 to 40 inches thick, but in some places it is as much as 50 inches thick. It ranges from black (N 2/0 to 10YR 2/1) to very dark brown (10YR 2/2). A few plant fibers occur on the surface layer and below the plow layer. The lower part of the organic layer contains as much as 50 percent mineral matter in some places.

The underlying material ranges from black (N 2/0 to 10YR 2/1) to olive gray (5Y 4/2 to 5Y 5/2). This material is typically silty clay loam, but in some places it is silt loam, loam, or clay loam. Lenses of sand are common. A few areas are sandy along the perimeters of the depression. Reaction is neutral or mildly alkaline.

Palms muck is in large depressions and is similar to the Blue Earth mucky silt loam and the Okoboji mucky silt loam, both of which are also in large depressions. In Palms muck, the organic layers are thicker and higher in organic-matter content. They lack the high carbonate content of the Blue Earth soils. All are in depressional areas and are very poorly drained.

221—Palms muck, 0 to 1 percent slopes. This nearly level organic soil is in depressions that formerly contained water much of the time. It is surrounded in most places by narrow rims of highly calcareous Harps soils. Individual areas range from about 80 acres to about 10 acres in size. Included in mapping were a few areas where the soil has some brown peat material.

Tile drains and open ditches are used to improve drainage. Runoff from adjacent slopes readily ponds on these soils. In periods of excess rainfall, crops are

sometimes damaged or destroyed before tile drains can remove the excess water. Drained areas are used for row crops, to which the soil is moderately suited. Small grain tends to lodge and produces grain of poor quality. Legumes for hay do poorly on these soils and are often winterkilled.

Partially drained areas are suited to permanent pasture of blue grass, bromegrass, or reed canarygrass. Undrained areas generally are suited only to wildlife habitat. Crops grow fairly well where this soil is adequately drained, fertilized, and well managed. Growth is generally better in years of somewhat limited rainfall than in years when rainfall is above average. Most of the acreage is managed as separate fields, but smaller areas are managed with the adjacent soils. Capability unit IIIw–2, environmental planting group 2.

Rolfe Series

The Rolfe series consists of very poorly drained, nearly level soils in depressions. These soils are on uplands throughout the county, but are mainly in the western half. They formed under native marsh grasses and sedges in glacial drift and local loamy alluvium.

In a representative profile the surface layer is black silt loam about 7 inches thick. The subsurface layer is dark gray and very dark gray, friable silt loam about 3 inches thick. The upper part of the subsoil is dark gray and very dark gray, firm light silty clay loam that has a few yellowish brown mottles. The lower part of the subsoil is very dark gray or olive gray, firm light silty clay, silty clay loam, and clay loam that has strong brown mottles. The substratum begins at a depth of about 42 inches. It is olive gray, friable sandy clay loam that is massive.

Rolfe soils have a high available water capacity. The subsoil is slowly permeable. Available nitrogen is low, available phosphorus is very low, and available potassium is very low to low. The organic-matter content is high. The surface layer is typically neutral or slightly acid. These soils have a high water table unless artificially drained. They are wet and are ponded after rains by runoff from surrounding soils.

Most areas are drained and cultivated. Some undrained areas are in cultivated fields. A few undrained areas are in pasture, and a few are suitable for development as wildlife habitat. Rolfe soils are managed with the associated soils, except for one or two areas that are large enough to be managed as individual fields.

Representative profile of Rolfe silt loam, 0 to 1 percent slopes, 600 feet north and 45 feet east of southwest corner sec. 28, T. 97 N., R. 33 W.

Ap—0 to 7 inches, black (10YR 2/1) mixed with grayish-brown (10YR 5/2) heavy silt loam; cloddy parting to weak, fine, granular structure; friable; neutral; abrupt, smooth boundary.

A2—7 to 10 inches, dark-gray (10YR 4/1) and very dark gray (10YR 3/1) silt loam; common, fine, faint, dark yellowish-brown (10YR 4/4) and few, fine, prominent, strong-brown (7.5YR 5/8) mottles; strong thin platy structure; friable; very fine silt coats on faces of dark-gray peds; common fine tubular pores; few black (10YR 2/1) worm casts; neutral; clear, wavy boundary.

AB—10 to 16 inches, dark-gray (5Y 4/1) light silty clay loam A2 material, 20 percent very dark gray (10YR 3/1) B material; few, very fine, distinct, yellowish-brown (10YR 5/6) mottles; moderate, fine and very fine, subangular blocky structure and weak, fine, platy; firm; neutral; clear, wavy boundary.

B21gt—16 to 26 inches, very dark gray (5Y 3/1) light silty clay; few, fine, prominent, strong-brown (7.5YR 5/6) mottles; moderate, fine, angular blocky structure; very firm; few very fine inped tubular pores; thin and medium continuous clay films on faces of peds; common very strong brown concretions (oxides); medium acid; gradual, smooth boundary.

B22gt—26 to 34 inches, olive-gray (5Y 5/2) light silty clay loam; gray (5Y 4/1) coats on faces of peds; common, fine, prominent, strong-brown concretions (oxides); medium acid; gradual, smooth boundary.

B23gt—34 to 42 inches, olive-gray (5Y 5/2) light clay loam; common, fine, prominent, strong-brown (7.5YR 5/6) mottles; weak, medium, subangular blocky structure; firm; common fine sand grains and few small pebbles; thin very dark gray (5Y 3/1) clay films covering 60 percent of faces of peds; very few fine black and common very fine strong-brown concretions (oxides); neutral; clear, smooth boundary.

C—42 to 60 inches, olive-gray (5Y 5/2) sandy clay loam; common, fine, prominent, yellowish-brown (10YR 5/8) mottles; massive; friable; few pebbles; very few fine black concretions (oxides); neutral.

The A1 or Ap horizons are silt loam, loam, or light silty clay loam 6 to 10 inches thick. They are black (10YR 2/1) or very dark gray (10YR 3/1). The A2 horizon is 3 to 8 inches thick and is generally dark gray (10YR 4/1) to gray (10YR 6/1). In some places it is very dark gray (10YR 3/1). The A2 horizon is silt loam or loam. Reaction in the A1 horizon and A2 horizon ranges from neutral to medium acid.

The B2 and B3 horizons are dark gray (5Y 4/1) to gray (5Y 5/1) or olive gray (5Y 4/2 to 5/2). The upper part of the B2 horizon is generally light clay or silty clay, but in a few places it is silty clay loam. The lower part is clay loam or loam.

The C horizon is typically clay loam, loam, or sandy clay loam.

The Rolfe soils in Palo Alto County are outside the range defined for the series, because they lack abrupt clay increases.

Compared with Okoboji soils, which are also in depressions, Rolfe soils have a thinner A horizon that is not so fine textured, and a B horizon that is higher in clay. Okoboji soils lack the gray A2 horizon.

274—Rolfe silt loam, 0 to 1 percent slopes. This nearly level soil is mainly in small, distinctly concave depressions in the uplands (fig. 19). It is generally surrounded by Webster or Nicollet soils, but in some places it is surrounded by Clarion soils. Most areas are 5 acres or less in size, but a few areas are as much as 20 acres.

Included with this soil in mapping are a few areas where both the surface layer and the light-colored subsurface layer have been mixed into the present plow layer. In these areas, the plow layer is generally gray when it is dry. Areas of about one-half acre or less are identified by spot symbols on the soil map.

Most of the acreage is used for row crops. Most of the acreage has been improved by artificial drainage, because this soil occurs in areas of other soils that are well suited to rowcropping. Most areas, however, are ponded in spring and after heavy rains. Tile drains do not remove water adequately, because the subsoil is clayey and is slowly permeable. Tile lines need to be placed closer in this soil than in other depressional soils

Figure 19.—**Small upland depression of Rolfe silt loam, 0 to 1 percent slopes. Rolfe soils are frequently ponded and are often too wet to plant in spring.**

in the county. Shallow surface ditches and surface intakes to tile lines are needed to remove excess surface water and reduce ponding.

Even if drainage is improved, this soil is slower to dry than surrounding soils and tillage is often delayed in spring. Crop growth is only moderate, and winterkilling and drowning out of legumes are common. This soil is generally managed with the surrounding soils. Capability unit IIIw-1, environmental planting group 2.

Salida Series

The Salida series consists of excessively drained soils. These soils are on small knobs or have short slopes between different levels of benches or outwash areas. Salida soils formed in coarse glacial debris under a native vegetation of prairie grasses.

In a representative profile the surface layer is very dark brown gravelly sandy loam about 7 inches thick. It is neutral in reaction. The subsoil is mixed very dark brown and dark brown to brown gravelly loamy sand about 6 inches thick. It is moderately alkaline in reaction. The substratum is mixed strong brown, yellowish brown, and grayish brown, loose, calcareous sand and gravel.

The Salida soils have a very low available water capacity and are very rapidly permeable. Available nitrogen, phosphorus, and potassium are very low. The surface layer ranges from neutral to moderately alkaline. The organic-matter content is low. Most of the water that falls on the surface is absorbed, but it rapidly drains through the soil and out of the plant root zone. Consequently, plants often lack enough available water. Soil blowing is a hazard if the surface is left bare.

Some small areas of less sloping Salida soils are cultivated with the associated soils. Large areas are managed as pasture. Some small areas in cultivated fields are left in forage grasses and then grazed along with the crop residue. Abandoned gravel pits are in many areas.

Representative profile of Salida gravelly sandy loam, 4 to 12 percent slopes, 740 feet south and 1,920 feet west of northeast corner SW¼ sec. 29, T. 97 N., R. 34 W., 130 feet east of road and 140 feet north of south fence:

A—0 to 7 inches, very dark brown (10YR 2/2) gravelly sandy loam, same color kneaded; weak, medium, granular structure; very friable; stones 1 to 2 inches in diameter on about 10 percent of surface, a few as much as 3 to 5 inches in diameter; neutral; clear, wavy boundary.

B—7 to 13 inches, 50 percent dark-brown (10YR 3/3), 25 percent brown (10YR 4/3), and 25 percent very dark brown (10YR 2/2) gravelly loamy sand; weak, coarse, granular structure; very friable; some vertical wedges of very dark brown (10YR 2/2); strong effervescence; moderately alkaline; gradual, irregular boundary.

C—13 to 60 inches, 50 percent yellowish-brown (10YR 5/8), 30 percent strong-brown (7.5YR 5/8), and 20 percent grayish-brown (10YR 5/2) sand and gravel; single grained; loose; horizontal layer grayish brown (2.5Y 5/2) to light brownish gray (2.5Y 6/2) between 28 and 31 inches; violent effervescence; moderately alkaline.

Unless eroded, the A horizon is about 7 to 10 inches thick. It is very dark brown (10YR 2/2) or very dark grayish brown (10YR 3/2). It is typically neutral in reaction, but in some places it is mildly alkaline or moderately alkaline and calcareous.

The B horizon is commonly discontinuous. It has hue of 10YR, value or 3 or 4, and chroma of 3 or 4. It is gravelly sandy loam or gravelly loamy sand about 4 to 8 inches thick.

Salida soils are neutral to moderately alkaline in the A and B horizons. They are typically calcareous within a depth of 14 inches and are calcareous throughout in some places.

The C horizon typically has hue of 10YR, value of 3 to 6, and chroma of 3 to 8. In other places it has hue of 7.5YR or 2.5Y.

Salida soils are calcareous nearer the surface and are shallower over sand and gravel than Estherville and Flagler soils. All are similar in drainage.

73C—Salida gravelly sandy loam, 4 to 12 percent slopes. This gently undulating to rolling soil is mainly on knobs and low hills where areas are generally small and irregular in shape. In a few outwash areas and on stream benches, this soil is on moderately sloping breaks. These areas are generally narrow and long. This soil is mainly with Clarion and Storden soils in the uplands and is adjacent to Estherville and Wadena soils in the outwash areas. In a few places Colo and Spillville soils are below areas of these soils.

Included with this soil in mapping are a few severely eroded areas where the surface layer is less than 3 inches thick. Also included are areas of soils, on the lower part of the slope, that are similar to Estherville soils and are leached of carbonates to a depth of about 20 inches.

Many areas are cultivated. Others are associated with steeper soils and are used for pasture. A few areas in cultivated fields are left in grass and are grazed in fall along with the residue from row crops.

This soil is susceptible to erosion and has low fertility. Crop growth is generally poor because of the lack of enough available water. Row crops can be planted on the contour. Crop residue left on the surface reduces the hazard of erosion. In a few places the gravel and small stones on the surface hinder tillage. Most areas are small and are generally managed with the adjacent soils. Capability unit IIIe-4, environmental planting group 4.

Spillville Series

The Spillville series consists of moderately well drained to somewhat poorly drained soils. These soils are on first bottoms and low foot slopes of 0 to 5 percent. The native vegetation is mainly prairie grasses. A few trees grow on the bottom land. Spillville soils formed in loamy alluvium.

In a representative profile the surface layer is black and very dark brown loam about 34 inches thick. The weakly developed subsoil is very dark grayish brown, friable light loam and fine sandy loam about 22 inches thick. The substratum is dark grayish brown, friable, massive loam.

Spillville soils have a high available water capacity and are moderately permeable. Available nitrogen is low or medium, available phosphorus is low, and available potassium is low. The surface layer is generally neutral to slightly acid. The organic-matter content is high.

The Spillville soils on bottom land are subject to flooding, and a few areas are channeled. Where flooding is not too severe, the areas are cultivated. Most, however, remain in grass or trees. On most foot slopes these soils receive runoff from adjacent slopes and are almost all used for row crops. Most areas are small and are managed with the adjacent soils.

Representative profile of Spillville loam, 0 to 2 percent slopes, 600 feet south and 1,100 feet west of northeast corner SE1/4 sec. 4, T. 97 N., 33 W.

Ap—0 to 8 inches, black (10YR 2/1) loam; cloddy parting to weak, fine, subangular blocky structure and moderate, fine, granular; friable; some clear sand grains on faces of peds; common fine roots; neutral; abrupt, smooth boundary.

A12—8 to 17 inches, black (10YR 2/1) loam; weak, fine, subangular blocky structure parting to moderate, medium, granular; friable; few fine tubular pores; common fine roots; some clear sand grains on faces of peds; neutral; gradual, smooth boundary.

A13—17 to 22 inches, very dark brown (10YR 2/2) loam; black (10YR 2/1) coatings on faces of peds; weak, medium, subangular blocky structure parting to moderate, medium, granular; friable; few fine tubular pores; common fine roots; clear sand grains on faces of peds that increase in abundance with increasing depth; neutral; gradual, smooth boundary.

A14—22 to 34 inches, very dark brown (10YR 2/2) loam, same color kneaded; black (10YR 2/1) coatings on faces of peds; high in very fine sand; weak, medium, subangular blocky structure parting to moderate, medium, granular; friable; few fine tubular pores; common fine roots; clear sand grains on faces of peds that increase in abundance with increasing depth; neutral; gradual, smooth boundary.

B1—34 to 42 inches, very dark grayish-brown (10YR 3/2) light loam; very dark brown (10YR 2/2) coatings on faces of peds; very high in fine sand; weak, medium, subangular blocky structure parting to weak, medium, granular; friable; few very fine dark-brown (7.5YR 3/2) concretions (oxides); few fine tubular pores; common fine roots; clear sand grains on faces of peds that increase in abundance with increasing depth; neutral; gradual, smooth boundary.

B2—42 to 56 inches, very dark grayish-brown (10YR 3/2) fine sandy loam, same color kneaded; very dark brown (10YR 2/2) coatings on faces of peds; weak, medium, subangular blocky structure parting to

weak, medium, granular; friable; few very fine dark-brown (7.5YR 3/2) concretions (oxides); few fine tubular pores; clear sand grains on faces of peds that increase in abundance with increasing depth; neutral; gradual, smooth boundary.

C—56 to 65 inches, dark grayish-brown (10YR 4/2) loam and very dark grayish-brown (10YR 3/2) coatings on cleavage faces; massive; friable; clear sand grains on cleavage faces; neutral.

The A horizon is typically black (10YR 2/1) or very dark brown (10YR 2/2), but it ranges to very dark gray (10YR 3/1) or very dark grayish brown (10YR 3/2) in the lower part. It is 30 to 50 inches thick.

The B horizon is weakly developed. Colors are usually within the range of the A horizon, but in some places this horizon is dark gray (10YR 4/1) or dark grayish brown (2.5Y 4/2). It is loam or sandy loam. A few to many brown, gray, or yellowish brown mottles are below a depth of 36 inches in places.

The C horizon has colors that are within the range of the A horizon, but in some places it is dark grayish brown (10YR 4/2 or 2.5Y 4/2), dark brown (10YR 3/3), brown (10YR 4/3), dark yellowish brown (10YR 4/4), or dark gray (10YR 4/1). It is loam, clay loam, or sandy loam. The reaction is commonly neutral or slightly acid, but in some places it is medium acid.

The Spillville soils contain more sand and less clay than Colo soils. They are also better drained than Colo soils. These soils are associated on bottom lands of the county.

485—Spillville loam, 0 to 2 percent slopes. This nearly level soil is on first bottoms adjacent to Colo, Wabash, and Spillville loam, channeled, soils. Most areas are nearly level, but some are gently undulating. In the gently undulating areas there are few, shallow, narrow, old stream channels. Most of the channels are filled with recent alluvium that is sandy, but a few are occupied by Colo soils. Most of these channels are ponded during wet seasons and influence the use and management of this soil. This soil has the profile described as representative of the series.

Included with this soil in mapping were a few areas that are dark grayish brown at a depth of about 30 inches. Also included are a few areas that have 4 to 6 inches of sandy overwash.

This soil is used for both row crops and pasture. The hazard of flooding in most areas limits the use of the soil to pasture. If flooding is controlled and old stream channels are filled, this soil is well suited to row crops.

Many areas are large enough to be managed as separate tracts. Most areas that are currently row cropped are small areas within larger fields of Colo or Wabash soils and are managed with them. A few large areas are managed separately. Many pastures have a few scattered trees. Capability unit IIw–2, environmental planting group 1.

485B—Spillville loam, 2 to 5 percent slopes. This gently sloping soil is on low, concave foot slopes and fans throughout the county. It is generally downslope from Clarion or Storden soils. It is typically upslope from soils on the bottom lands or benches. In a few places it is upslope from Webster or Nicollet soils. Areas are narrow and are generally about 5 to 10 acres in size. A few areas are as large as 20 acres.

This soil has a profile similar to the one described as representative of the series, but the substratum is generally dark brown or dark yellowish brown clay loam.

Included with this soil in mapping are a few areas where the browner substratum is at a depth of about 30 inches. Also included are areas that are dark grayish brown at a depth of about 30 inches.

Some of the acreage is used for row crops, to which the soil is well suited if it is protected against erosion. Some areas that are adjacent to steep soils are used for pasture.

Diversion terraces upslope control runoff from higher areas. The gullies that form in shallow drainageways can be shaped and seeded and used as waterways. Crops grow well under good management. Areas that are used for row crops are generally managed with Colo or other bottom land soils and with soils on benches. Capability unit IIe–1, environmental planting group 1.

C485—Spillville loam, channeled, 0 to 2 percent slopes. This nearly level soil is on the first bottoms adjacent to streams. Areas are dissected by oxbows and meandering stream channels and are the first to be flooded when streams overflow (fig. 20). Some areas are long and narrow, paralleling the stream. Where oxbows are more numerous, individual areas of this soil are large. The vegetation is grass, brush, and trees. This soil is adjacent to other Spillville soils and Colo or Wabash soils.

This soil is similar to the one described as representative of the series, but the substratum contains more sand and the surface layer generally contains more sand.

Included with this soil in mapping are a few areas, adjacent to streams, that are stratified silty, loamy, or sandy material. In a few places, this material is light colored and is moderately alkaline. Floods sometimes deposit a thin layer of sediments. Also included are some areas of channeled soils that are like Colo soils. They are mainly silty clay loam or clay loam.

Flooding is a severe hazard. Most of the acreage is in grass, brush, and trees. Some areas are used for pasture. Most areas provide good habitat for wildlife. Areas that are far enough from the stream and not flooded so frequently are farmed.

If flooding is controlled, old stream channels filled, and the brush and trees cleared, this soil is well suited to row crops. Capability group Vw–1, environmental planting group 1.

Storden Series

The Storden series consists of somewhat excessively drained soils on uplands. These soils formed in glacial till. Storden soils are on sharply convex knobs and side slopes in the rolling uplands throughout the county. Slope ranges from 2 to 25 percent. The native vegetation was prairie grasses.

In a representative profile the surface layer is very dark brown, mildly alkaline loam about 6 inches thick. The next 4 inches is very dark gray and brown, moderately alkaline loam. The substratum is yellowish brown in the upper part and grades to light olive brown at a depth of about 40 inches. It is moderately alkaline loam.

The Storden soils have a high available water ca-

Figure 20.—**One of the few cultivated fields of Spillville loam, channeled, 0 to 2 percent slopes. Many old meandering channels, such as the one in the center, cross these soils and interfere with tillage.**

pacity, but at many times are not at capacity because water readily runs off some slopes. Permeability is moderate. These soils contain excess lime throughout the profile and are generally mildly alkaline in the surface layer. The substratum is moderately alkaline. Available nitrogen, phosphorus, and potassium are very low. The organic-matter content is low.

Storden soils erode if the surface layer is bare or if vegetation is sparse. Runoff and low fertility are limitations. The less sloping Storden soils are cultivated with the associated soils. The steeper areas are used as pasture.

Representative profile of Storden loam, 9 to 14 percent slopes, 42 feet west and 480 feet north of southeast corner sec. 26, T. 94 N., R. 34 W., on a convex 11 percent, east-facing slope in a bluegrass pasture:

A1—0 to 6 inches, very dark brown (10YR 2/2) loam mixed with dark brown (10YR 4/3) in lower part, very dark grayish brown (10YR 3/2) kneaded; weak, fine, granular structure; friable; abundant roots; slight effervescence; mildly alkaline; clear, smooth boundary.

AC—6 to 10 inches, very dark gray (10YR 3/1) and brown (10YR 4/3) loam; moderate, fine, subangular blocky structure; friable; abundant roots; strong effervescence; moderately alkaline; clear, smooth boundary.

C1—10 to 17 inches, yellowish-brown (10YR 5/4) loam; moderate, fine, subangular blocky structure; friable; common dark-gray (10YR 4/1) worm casts; violent effervescence; moderately alkaline; gradual, smooth boundary.

C2—17 to 31 inches, yellowish-brown (10YR 5/4) loam; few, fine, faint, dark yellowish-brown (10YR 4/4) mottles; weak, coarse, prismatic structure; friable; common, fine, distinct, strong-brown (7.5YR 5/6) and few, fine, distinct, reddish-brown (5Y 4/4) concretions (oxides) that are readily crushed; violent effervescence; moderately alkaline; diffuse, smooth boundary.

C3—31 to 40 inches, yellowish-brown (10YR 5/4) and some light olive-brown (2.5Y 5/4) loam; mottles are common fine distinct strong brown (7.5YR 5/6), few fine distinct reddish brown (5YR 4/4), and few fine faint pale brown (10YR 6/3); massive; friable; few reddish-brown concretions (oxides) that are readily crushed; violent effervescence; moderately alkaline; diffuse, smooth boundary.

C4—40 to 60 inches, light olive-brown (2.5Y 5/4) loam; common, fine, distinct, strong-brown (7.5YR 5/6) mottles; massive; friable; few fine calcium carbonate accumulations in soft rounded masses; common fine black and strong-brown concretions (oxides); violent effervescence; moderately alkaline.

The A1 horizon is very dark gray (10YR 3/1), very dark grayish brown (10YR 3/2), very dark brown (10YR 2/2), or dark brown (10YR 3/3) friable loam or light clay loam

3 to 6 inches thick. The Storden soils in Palo Alto County have a darker colored A horizon than typical for the Storden series. The Ap horizon is dark grayish brown (10YR 4/2) or brown (10YR 4/3) and in severely eroded areas it is yellowish brown (10YR 5/4). The AC horizon is very dark gray (10YR 3/1), brown (10YR 4/3), dark grayish brown (10YR 4/2), or dark yellowish brown (10YR 4/4) and is as much as 6 inches thick.

The C horizon is dark yellowish brown (10YR 4/4) to yellowish-brown (10YR 5/6) friable loam or light clay loam to a depth between 20 and 40 inches. Below this it is typically light olive brown (2.5Y 5/4) or yellowish brown (10YR 5/4) with grayish brown (10YR 5/2), olive gray (5Y 5/2), or strong brown (7.5YR 5/6) mottles. In some places pockets of sand and gravel are in the profile.

Storden soils have a thinner A horizon than the adjacent Clarion soils and are not so deep to calcium carbonate. They lack the B horizon that is typical of Clarion soils. Storden soils are not so gravelly or sandy as Salida soils, which are generally adjacent to Storden soils.

62C—Storden loam, 5 to 9 percent slopes. This moderately sloping soil is on short convex side slopes adjacent to steeper Storden soils. Other areas are on sharply convex knolls associated with Clarion soils or areas that rise out of nearly level soils. Areas are 5 to 10 acres in size.

In pastured areas this soil has a profile similar to the one described as representative of the series. In plowed areas, the plow layer is mixed with the yellowish brown substratum and is lighter in color. In places the substratum is exposed.

Included with this soil in mapping are severely eroded areas. The larger areas are identified on the soil map by spot symbols. Also included are a few areas one-half acre or less of Salida soils and a few areas where the substratum is silty.

Most of the acreage is cultivated. A few areas are pastured. The erosion hazard is moderate and fertility is low. If erosion is controlled and fertility improved, the soil is well suited to row crops. In places the small size, the shape of areas, and the irregular slopes make erosion control difficult.

Crop growth is good if large additions of fertilizer are added. This soil is generally managed with Clarion soils or other Storden soils, but in places it is managed with Nicollet and Webster soils. Areas that are in pasture are generally adjacent to steeper Storden soils. Capability unit IIIe–1, environmental planting group 3.

62D—Storden loam, 9 to 14 percent slopes. This strongly sloping soil is on short convex side slopes, knobs, and ridges. It is adjacent to Clarion soils, other Storden soils, and upslope from steeper Storden soils or Spillville and Colo soils. Many areas are 5 to 10 acres in size, but some are larger. A few areas are as large as 30 acres. This soil has the profile described as representative of the series. In cultivated areas, the plow layer is lighter in color than in other places. In places the yellowish brown substratum is exposed.

Included with this soil in mapping are severely eroded areas. The larger areas are identified by spot symbols. Also included are a few areas one-half acre or less of Salida soils.

Most of the acreage is cultivated. Some areas are in pasture. Runoff is rapid, the hazard of erosion is moderately severe, and fertility is low.

This soil is moderately suited to row crops if erosion is controlled. Improving fertility and using practices that allow more water to soak into this soil improve crop growth. Erosion control is difficult in places because of the size and shape of areas. Pasture is often the best use, especially in areas associated with steeper soils. Most areas are managed with the adjacent soils, which generally are moderately or strongly sloping. The rest is generally managed with steeper Storden soils. Capability unit IIIe–2, environmental planting group 3.

62E—Storden loam, 14 to 18 percent slopes. This moderately steep soil is on hills and ridges and on side slopes along drainageways and small streams. It is adjacent to Clarion and other Storden soils. Most areas are upslope from Spillville and Colo soils. Most are 5 to 10 acres in size, but a few are as large as 20 acres.

In uncultivated areas this soil has a profile similar to the one described as representative of the series. In most cultivated areas the plow layer is lighter colored. In some places the yellowish brown substratum is exposed.

Included with this soil in mapping and identified by spot symbols on the soil map are some severely eroded areas. Also included are a few areas one-half acre or less of Salida soils. Also included are a few places adjacent to small upland waterways where the surface layer is thicker than typical.

This soil is used for both pasture and cultivated crops. It is droughty during periods of low rainfall, and the hazard of erosion is serious because of rapid runoff. Fertility is low.

This soil is suited to pasture. It can be used for row crops if erosion is controlled and fertility improved. Controlling runoff and allowing more water to enter the soil improve pasture and crop growth. Erosion control is difficult in places because of the size and shape of areas and the steep irregular slopes. Most of the acreage is managed with adjacent soils. Capability unit IVe–1, environmental planting group 3.

62F—Storden loam, 18 to 25 percent slopes. This steep soil is on short convex side slopes. It is upslope from Spillville or Colo soils and downslope from Clarion soils or less sloping Storden soils. Areas range from about 5 to 15 acres in size.

This soil is similar to the one described as representative of the series, but in most places the surface layer is only about 4 inches thick. In some areas the surface layer is about 10 inches thick, and in a few slopes are as steep as 40 percent, mainly along the West Fork of the Des Moines River and in areas bordering some of the lakes. In some places the yellowish brown substratum is exposed.

Included in mapping and identified on the soil map by spot symbols are some severely eroded areas. A few areas one-half acre or less of Salida soils are also included.

About all of the acreage is used for pasture, to which it is best suited. Erosion is a hazard. Low fertility limits plant growth. Crops often lack enough available water during periods of low rainfall because of rapid runoff.

Improving fertility and controlling runoff to allow more water to enter this soil improve crop growth. The

soil is managed as separate fields or with other adjacent steep soils. In a few places, tillage is difficult because of large rocks and boulders and irregular slopes. Capability unit VIe–1, environmental planting group 3.

639C—Storden-Salida complex, 5 to 9 percent slopes. This gently rolling mapping unit is on irregular convex side slopes and ridges. It is upslope from some of the steeper Storden-Salida complexes, and below the Clarion-Estherville complex. In places it is above Colo-Spillville complex. Individual areas range from about 5 to 15 acres in size.

This mapping unit is about 50 percent Storden loam, 25 percent Salida gravelly sandy loam, and 25 percent less extensive soils, which are extremely variable in texture and depth of leaching within short distances. Sandy soils that resemble Dickman soils and silty soils that resemble Truman soils are two minor soils. They differ from those soils in being calcareous at or near the surface in many places. In places yellowish brown substratum material is exposed at the surface. Areas one-half acre or less where the surface layer is gravelly are identified by spot symbols on the soil map.

Most areas are cultivated. A few are pastured. The soils are used for row crops but are more suitable for hay and pasture crops. Permeability is moderate to very rapid. Nearly all the soils in this complex have low fertility, low available water capacity or both. All are readily eroded by water, and on all but Storden soils, the hazard of soil blowing is severe.

Erosion control is difficult in places because of the size, the shape of areas, and the irregular slopes. Crop growth is moderate to good on the Storden soils, but is generally poor or moderate on the rest. Capability unit IIIe–4, environmental planting group 4.

639D—Storden-Salida complex, 9 to 14 percent slopes. This rolling mapping unit is on irregular, convex side slopes below the Clarion-Estherville complex and the less sloping Storden-Salida complex and above Colo and Spillville soils. Individual areas range from about 5 to 10 acres.

This mapping unit is about 50 percent Storden loam, 25 percent Salida gravelly sandy loam, and 25 percent less extensive soils, which are extremely variable in texture and depth of leaching within short distances. Sandy soils similar to the Dickman soils and silty soils similar to the Truman soils are two less extensive soils. They differ from those soils in being calcareous at or near the surface in many places. In places yellowish brown substratum material is exposed at the surface. Areas one-half acre or less where the surface is gravelly are identified by a spot symbol on the soil map.

These soils are used for pasture and occasionally for row crops. They are better suited to hay and pasture. They are moderately permeable to very rapidly permeable. Nearly all are low in fertility, or they do not provide enough available water for crops. All are subject to water erosion. All but Storden soils are subject to soil blowing.

Crop growth is moderate to good on Storden soils, but generally is poor to moderate on the rest. Capability unit IIIe–4, environmental planting group 4.

639E—Storden-Salida complex, 14 to 18 percent slopes. This hilly mapping unit is on irregular, convex side slopes below Clarion-Estherville complex and the less sloping Storden-Salida complex and upslope from Spillville soils, which are on narrow foot slopes. Individual areas generally are about 5 to 15 acres in size.

This mapping unit is about 50 percent Storden loam, 25 percent Salida gravelly sandy loam, and 25 percent less extensive soils, which are extremely variable in texture and depth of leaching within short distances. Sandy soils similar to Dickman soils and silty soils similar to Truman soils are two less extensive soils. They differ from those soils in being calcareous at or near the surface in many places. In most areas that extend into cultivated fields, yellowish-brown substratum material is exposed at the surface. Areas one-half acre or less where the surface layer is gravelly are identified by spot symbols on the soil map.

All the acreage is used for pasture, except for small parts that extend into cultivated areas. This mapping unit is suitable for pasture. Plant growth is moderate or poor because most of the soils are low in fertility or do not provide crops enough available water. Permeability is moderate to very rapid. Fertilization improves the plant growth if fertilizer is applied in fall or very early in spring before a lack of water limits growth. Erosion is a serious hazard if pasture is overgrazed. Capability unit IVe–2, environmental planting group 4.

Talcot Series

The Talcot series consists of poorly drained, nearly level soils that are calcareous throughout their profile. These soils are in outwash areas, on stream benches, and in valley trains throughout the county. The native vegetation was marsh grasses, sedges, and prairie grasses that tolerate wetness.

In a representative profile the surface layer is black clay loam about 18 inches thick. The subsoil is very dark gray grading to dark gray, gray, olive gray, and olive. It is friable clay loam in the upper part and grades to loam and sandy clay loam. It has olive mottles. Beginning at a depth of about 39 inches, the substratum is mixed grayish brown and gray, calcareous, loose sand and gravel.

Talcot soils have a moderate available water capability. Permeability is moderate in the upper part and rapid or very rapid in the underlying sand and gravel. These soils are moderately alkaline throughout the profile. Available nitrogen is medium or low, available phosphorus is very low, and available potassium is very low to low. Available iron is low in places. The organic-matter content is high.

Talcot soils are wet because of a high water table. Where drained, they are well suited to row crops. Areas vary; some are large. Larger areas are generally managed with the adjacent soils. Some are managed separately.

Representative profile of Talcot clay loam, deep, 0 to 2 percent slopes, 840 feet west and 75 feet north of southeast corner NE¼NE¼ sec. 13, T. 94 N., R. 33 W.

Ap—0 to 8 inches, black (N 2/0) clay loam; moderate, fine, granular structure; friable; common fine roots;

strong effervescence; moderately alkaline; abrupt, smooth boundary.

A12—8 to 18 inches, black (N 2/0) clay loam; moderate, fine, granular structure with some weak, fine, subangular blocky; friable; common fine roots; strong effervescence; moderately alkaline; gradual, smooth boundary.

B1—18 to 24 inches, very dark gray (10YR 3/1) and dark gray (10YR 4/1) clay loam; moderate, fine, granular structure and weak, fine, subangular blocky; friable; strong effervescence; moderately alkaline; gradual, smooth boundary.

B21—24 to 29 inches, gray (5Y 5/1) clay loam; few, fine, faint, olive (5Y 5/3) mottles; few dark gray (5Y 4/1) coats on faces of peds; weak, fine, subangular blocky structure; friable; few fine roots; strong effervescence; moderately alkaline; gradual, smooth boundary.

B22—29 to 34 inches, gray (5Y 5/1) loam; few, fine, faint, olive (5Y 5/3) mottles; weak, fine, subangular blocky structure; friable; few fine calcium carbonate accumulations in soft rounded masses; strong effervescence; moderately alkaline; clear, smooth boundary.

B3—34 to 39 inches, olive-gray (5Y 5/2) and olive (5Y 5/3) sandy clay loam; weak, medium, subangular blocky structure; friable; few fine calcium carbonate accumulations in soft rounded masses; few fine black concretions (oxides); strong effervescence; moderately alkaline; clear, wavy boundary.

IIC—39 to 60 inches, mixed grayish-brown (10YR 5/2) and gray (5Y 6/1) sand and gravel; slightly cemented to single grained; loose; few fine black concretions (oxides); strong effervescence; moderately alkaline.

The A horizon is about 14 to 24 inches thick. It typically ranges from black (N 2/0 or 10YR 2/1) to very dark gray (10YR 3/1 or N 3/0). It is typically clay loam, but in some places it is silty clay loam or sandy clay loam.

The B horizon ranges from dark gray (5Y 4/1) to olive gray (5Y 5/2). It has hue of 2.5Y in some places. It is mainly dark grayish brown (2.5Y 4/2) or grayish brown (2.5Y 5/2). It is typically clay loam, but it ranges to loam or sandy clay loam in the lower part.

The C horizon upper boundary is generally at a depth of 32 to 40 inches.

Unlike the Biscay soils, Talcot soils are calcareous throughout their profile. Except for the underlying sand and gravel, they resemble Canisteo soils. They contain less lime than Harps soils, which do not overlie sand and gravel. All are poorly drained.

559—Talcot clay loam, deep, 0 to 2 percent slopes. This nearly level soil is in outwash areas and on stream benches with Mayer, Biscay, Cylinder, and Wadena soils. Individual areas range from about 10 to more than 100 acres in size.

Included with this soil in mapping are some areas where the depth to sand and gravel is about 48 inches. In these areas the surface layer is commonly somewhat deeper than the one in the representative profile. Also included and identified by spot symbols on the soil map are a few areas one-half acre or less of Okoboji soils and areas of highly calcareous soils that have a dark-gray surface layer when dry. In these areas, available phosphorus and potassium are likely to be very low, and available iron and other minor elements are commonly deficient.

This soil is poorly drained, and a few areas are flooded during periods of unusually high rainfall. Drainage can be improved by tile drains. Tile drains function well, but in some places, instability of the substratum makes installation difficult.

Where drainage is improved, the soil is well suited to row crops. If management is good and fertility is maintained, crops grow well. Larger areas are managed separately. Other areas are managed with the adjacent soils. Capability unit IIw-5, environmental planting group 2.

Truman Series

The Truman series consists of well drained soils on uplands near streams and lakes. These soils formed under native prairie grasses in silty, water-deposited material. They have convex slopes that range from 0 to 6 percent.

In a representative profile the surface layer is very dark brown and very dark gray, neutral silt loam about 15 inches thick. The subsoil also is neutral silt loam about 39 inches thick. It is brown and dark yellowish brown in the upper part and dark yellowish brown and yellowish brown in the lower part. The substratum begins at a depth of about 54 inches. It is yellowish brown, mildly alkaline loam.

The Truman soils have high available water capacity and are moderately permeable. Available nitrogen, phosphorus, and potassium are low. Typically, the surface layer is neutral in reaction. The organic-matter content is high.

Most of the acreage is cultivated. Individual areas are small and managed with the adjacent soils. The more sloping areas readily erode if the surface is left bare.

Representative profile of Truman silt loam, 2 to 6 percent slopes, 750 feet south and 45 feet east of northwest corner sec. 33, T. 97 N., R. 32 W.

Ap—0 to 8 inches, mixed very dark brown (10YR 2/2) and very dark gray (10YR 3/1) silt loam, very dark grayish brown (10YR 3/2) to dark grayish brown (10YR 4/2) dry, very dark brown (10YR 2/2) to very dark gray (10YR 3/1) kneaded; cloddy parting to weak, medium, granular structure; friable; few very fine strong-brown to dark-brown concretions (oxides); neutral; clear, smooth boundary.

A12—8 to 15 inches, 75 percent very dark brown (10YR 2/2) and 25 percent very dark gray (10YR 3/1) silt loam, very dark brown (10YR 2/2) to very dark gray (10YR 3/1) kneaded; common, fine, faint, dark-brown or brown (10YR 3/3 to 4/3) mottles; predominantly weak, medium, granular structure and weak, fine, subangular blocky; friable; neutral; clear, smooth boundary.

B1—15 to 24 inches, 60 percent brown (10YR 4/3) and 40 percent dark yellowish-brown (10YR 4/4) silt loam; dark yellowish brown (10YR 3/4) to brown (10YR 4/3) kneaded; brown (10YR 4/3) and dark-brown (10YR 3/3) coatings on faces of peds; common, fine, faint, yellowish-brown (10YR 5/4) mottles; weak, fine, subangular blocky structure parting to weak, medium, granular; friable; few very dark gray (10YR 3/1) worm casts and fills in old root channels; very few thin discontinuous clay films on some faces of peds; neutral; clear, smooth boundary.

B21—24 to 33 inches, dark yellowish-brown (10YR 4/4) to yellowish-brown (10YR 5/6) and 15 percent dark grayish-brown (10YR 4/2) heavy silt loam, yellowish brown (10YR 5/4) kneaded; weak, medium, prismatic structure parting to weak, fine and medium, subangular blocky; friable; very dark brown to strong-brown concretions (oxides); very few thin discontinuous clay films on some faces of peds and

in some old root channels; neutral; gradual, smooth boundary.

B22—33 to 42 inches, dark yellowish-brown (10YR 4/4) to yellowish-brown (10YR 5/6) heavy silt loam, yellowish brown (10YR 5/6 to 5/8) kneaded; dark yellowish-brown (10YR 4/4) coatings on faces of peds; weak, medium, prismatic structure parting to weak, fine and medium, subangular blocky; friable; very dark grayish-brown worm casts; few very fine dark-brown to strong-brown concretions (oxides) and few very fine black concretions (oxides); neutral; gradual, smooth boundary.

B3—42 to 54 inches, mixed dark yellowish-brown (10YR 4/4) and yellowish-brown (10YR 5/6) medium silt loam, yellowish brown (10YR 5/4 to 5/6) kneaded; few, fine, faint, brown (10YR 4/3) and strong-brown (7.5YR 5/6) mottles; weak, medium, prismatic structure parting to weak, fine and medium, subangular blocky; very friable; common fine dark-brown to strong-brown concretions (oxides); neutral; gradual, smooth boundary.

C—54 to 66 inches, yellowish-brown (10YR 5/4) loam; common medium distinct grayish-brown (10YR 5/2) mottles; few streaks (usually horizontal bands) of dark brown to brown (7.5YR 4/4) to strong brown (7.5YR 5/6 to 5/8); massive; very friable; common fine black concretions (oxides); slight effervescence; mildly alkaline.

The A horizon is 8 to 16 inches thick and is medium or heavy silt loam. It is black (10YR 2/1), very dark brown (10YR 2/2), or very dark gray (10YR 3/1). It typically has granular structure, but has subangular blocky structure in the lower part in some places. It is neutral to slightly acid.

The B horizon ranges from 20 to 40 inches in thickness and is typically light silt loam or heavy silt loam. In a few places the B2 horizon is light silty clay loam, and in places the B3 horizon is loam or very fine sandy loam. The upper part of the B horizon is brown (10YR 4/3), dark yellowish brown (10YR 4/4), or yellowish brown (10YR 5/4). A few darker coats on faces of peds are common. The rest of the B horizon is dark yellowish brown (10YR 4/4) and yellowish brown (10YR 5/4–5/6).

The C horizon is yellowish-brown (10YR 5/4) or grayish-brown (10YR 5/2) silt loam, loam, or very fine sand. It is mildly alkaline or moderately alkaline.

Truman soils have more uniform material throughout their profile than Clarion soils. They have less sand and more clay than Dickman soils, which formed in similar material.

339—Truman silt loam, 0 to 2 percent slopes. This nearly level soil is mostly on a high stream bench in West Bend Township. It is adjacent to Webster, Dickman, and other Truman soils. In the uplands it is adjacent to Clarion, Nicollet, Dickman, or Waldorf soils. In a few places this soil borders soils that are on stream benches. Slopes are slightly convex. Individual areas are about 20 acres or more in size.

This soil has a profile similar to the one described as representative of the series, but the surface layer is slightly thicker.

Included with this soil in mapping are a few small areas where slopes are slightly concave. In these areas the surface layer and subsoil are silty clay loam. These areas are somewhat slower to dry after rains.

All the acreage is cultivated. This soil is well suited to row crops. Seedbeds are easily prepared. Soil blowing can be serious if the soil is plowed in fall and the surface is left bare. Most areas are managed with the adjacent soils, but some areas are large enough to be managed separately. Capability unit I–1, environmental planting group 1.

339B—Truman silt loam, 2 to 6 percent slopes. This gently sloping to moderately sloping soil is on uplands along streams or near lakes. Most areas are adjacent to Clarion, Nicollet, or Dickman soils. A few are adjacent to other Truman soils. Slopes are short and convex. Individual areas are typically 5 to 15 acres in size. This soil has the profile described as representative of the Truman series.

Included with this soil in mapping are a few areas where the surface layer is very fine sandy loam. On the steeper slopes, the surface layer is only about 10 inches thick. Also included are a few areas where the surface layer and subsoil are silty clay loam. In these areas it is somewhat more difficult to prepare a desirable seedbed. These areas are also somewhat slower to dry after rains.

Most of the acreage is cultivated. This soil is well suited to row crops if erosion is controlled. Planting row crops on the contour or terracing helps control erosion. Seedbeds are easily prepared and crop growth is good. Soil blowing is sometimes a problem, and plowing in fall should be avoided. This soil is managed with the adjacent soils. Capability unit IIe–1, environmental planting group 1.

Wabash Series

The Wabash series consists of very poorly drained, nearly level soils on low bottom land along the major streams. Wabash soils formed in fine-textured alluvium on the lowest part of first bottoms. The native vegetation was marsh grasses and sedges and in places a few scattered trees.

In a representative profile the surface layer is black silty clay about 25 inches thick. The subsoil to a depth of about 70 inches is black, firm silty clay.

The Wabash soils have moderately high available water capacity. They hold a large amount, but because of the fine texture much of this water is not available to plants. During extremely dry weather, large cracks form and break crop roots. These soils are very slowly permeable. Available nitrogen is low to medium, available phosphorus is very low, and available potassium is very low to low. The surface layer is generally neutral to slightly acid. The organic-matter content is high. Wabash soils have a high water table, and most areas are flooded during periods of high rainfall.

Where these soils are drained, corn and soybeans are grown. Undrained areas are in pasture. Some areas are large enough to be managed as individual fields. Smaller areas are managed with adjacent soils.

Representative profile of Wabash silty clay, 0 to 2 percent slopes, 1,000 feet north and 30 feet east of southeast corner SW¼SW¼ sec. 29, T. 95 N., R. 31 W.

A11—0 to 9 inches, black (N 2/0) light silty clay; moderate, fine, granular structure and very fine, subangular blocky; firm; common fine roots; neutral; clear, smooth boundary.

A12—9 to 17 inches, black (N 2/0) silty clay; moderate, medium, granular structure and weak, medium, subangular blocky; firm; common fine roots; neutral; gradual, smooth boundary.

A13—17 to 25 inches, black (N 2/0) silty clay; weak, fine, prismatic structure parting to moderate, medium, granular and very fine subangular blocky; firm; few fine roots; neutral; gradual, smooth boundary.

B1—25 to 33 inches, black (N 2/0) silty clay; weak, medium, prismatic structure parting to moderate, medium, subangular and angular blocky; firm; continuous, shiny faces of peds; neutral; gradual, smooth boundary.

B21—33 to 41 inches, black (N 2/0) silty clay; few, moderate, faint, very dark grayish-brown (2.5Y 3/2) mottles; weak, medium, prismatic structure parting to moderate, fine and medium, subangular and angular blocky; firm; continuous shiny faces of peds; few, very fine, moderately hard, strong-brown concretions (oxides); neutral; gradual, smooth boundary.

B22—41 to 56 inches, black (5Y 2/1) silty clay; few fine, faint, very dark grayish-brown (2.5Y 3/2) mottles; weak, fine and medium, prismatic structure parting to moderate, fine, subangular blocky; firm; continuous shiny faces of peds; common, fine, moderately hard, strong-brown concretions (oxides); neutral; diffuse, smooth boundary.

B3—56 to 70 inches, black (5Y 2/1) light silty clay; few, fine, faint, dark grayish-brown (2.5Y 4/2) mottles; weak, medium, prismatic structure parting to weak, medium, subangular blocky; firm; few very fine tubular pores; few, fine, moderately hard, strong-brown and black concretions (oxides); neutral.

The A horizon is 20 to 35 inches thick. It is black (N 2/0, 10YR 2/1, or 5Y 2/1). It is dominantly silty clay, but it is heavy silty clay loam in the plow layer in some places. Structure is moderate to strong and fine to medium, granular and subangular blocky.

The B horizon ranges from black (N 2/0 or 5Y 2/1) to very dark gray (5Y 3/1 or N 3/0). Structure ranges from moderate to strong, subangular blocky to angular blocky. Reaction is neutral to slightly acid.

The C horizon is at a depth of 36 to more than 70 inches. It is silty clay, silty clay loam, clay loam, or sandy clay loam.

Wabash soils are finer textured, are more poorly drained, and have stronger structure than the adjacent Colo soils.

172—Wabash silty clay, 0 to 2 percent slopes. This nearly level soil is on the bottom lands of the major streams and their tributaries. It is nearly level or in slight depressions. It generally is on the border bottoms and is adjacent to Colo soils. Most areas are fairly large, ranging from 10 to 30 acres.

Wetness and flooding limit the use of this soil for cropping. Often the water table is high; in places it is about the level of water in nearby streams. Tile drains are not satisfactory because the subsoil is very slowly permeable and adjacent outlets are lacking. In areas where tile drains can be used, spacing of the lines should be closer in this soil than in most other poorly drained soils. In some places surface drainage can be improved by shallow ditches.

Where flooding is not too frequent and drainage is improved, this soil is suited to row crops. Other areas are used for pasture. Even where drainage is improved, crop growth is sometimes only moderate, because the high clay content of the subsoil restricts the movement of air and water. Runoff is slow. The surface layer is clayey, dries slowly after rains, and is difficult to work. If tilled when wet, it becomes cloddy. In extremely dry weather, large cracks form. This soil is generally flooded when streams overflow. Flooding is frequently early in the season but is sometimes late enough to delay fieldwork. It seriously limits the use of this soil for cultivated crops. Capability unit IIIw-3, environmental planting group 2.

Wacousta Series

The Wacousta series consists of very poorly drained, nearly level soils in large depressions in the uplands. The depressions are generally the beds of former shallow lakes. These soils formed under native marsh grasses and sedges in silt water-worked glacial sediments or local alluvium.

In a representative profile the surface layer is black silty clay loam about 13 inches thick. The calcareous subsoil is olive gray, friable silty clay loam that has light brownish gray, yellowish brown, and light olive brown mottles. The calcareous substratum begins at a depth of about 21 inches. It is olive gray, dark gray, and gray, friable silty clay loam in the upper part and silt loam in the lower part. It has mottles of strong brown, yellowish brown, and olive. Soft rounded accumulations of calcium carbonate are common in the subsoil and substratum.

The Wacousta soils have a high available water capacity and are moderately permeable or moderately slowly permeable. They have a high water table unless artificially drained. They are wet, and runoff from surrounding soils ponds for short periods after rains. Available nitrogen is medium or low, and available phosphorus and potassium are very low. The organic-matter content is high. The surface layer is neutral or alkaline.

Most areas are drained and used for cultivated crops, but a few areas are in pasture. Some areas of Wacousta soils are managed separately, but most are managed with the adjacent soils. A few undrained areas are suitable for development as wildlife habitat.

Representative profile of Wacousta silty clay loam, 0 to 1 percent slopes, 246 feet north and 234 feet west of southeast corner NE¼ sec. 17, T. 95 N., R. 31 W.

Ap—0 to 5 inches, black (N 2/0) silty clay loam; weak, fine and very fine, granular structure; friable; neutral; abrupt, smooth boundary.

A12—5 to 10 inches, black (N 2/0) silty clay loam; weak, fine, granular structure; friable; mildly alkaline; clear, smooth boundary.

A3—10 to 13 inches, black (10YR 2/1) silty clay loam; common, fine, faint, very dark gray (10YR 3/1) mottles in lower part; weak, fine, subangular blocky and weak, fine, granular structure; friable; mildly alkaline; clear, smooth boundary.

B2g—13 to 21 inches, olive-gray (5Y 5/2) silty clay loam; mottles are few medium faint light brownish gray (2.5Y 6/2), few fine distinct yellowish brown (10YR 5/4), and few fine distinct light olive brown (2.5Y 5/6); weak, very fine, subangular blocky structure; friable; common fine calcium carbonate accumulations in soft rounded masses; few fine manganese concretions (oxides); strong effervescence; moderately alkaline; gradual, smooth boundary.

C1g—21 to 33 inches, olive-gray (5Y 5/) silty clay loam; mottles are common fine prominent strong brown (7.5YR 5/8), common fine faint olive (5Y 5/4), and few fine faint dark gray (5Y 4/1); massive; friable; few fine and medium tubular pores; common very fine calcium carbonate accumulations in soft rounded masses, a few as much as one-half inch in diameter; few medium black concretions (oxides); strong effervescence; moderately alkaline; gradual, smooth boundary.

C2g—33 to 41 inches, gray (5Y 5/1) silty clay loam; mottles are common fine prominent strong brown (7.5YR 5/8) and few fine faint olive (5Y 5/4); massive;

friable; few fine tubular pores; few fine calcium carbonate accumulations in soft rounded masses, a few more than 1 inch in diameter; strong effervescence; moderately alkaline; gradual, smooth boundary.

C3g—41 to 48 inches, dark-gray (5Y 4/1) silty clay loam; mottles are common fine faint yellowish brown (10YR 5/6) and common fine faint olive gray (5Y 5/2); massive; friable; few fine calcium carbonate accumulations in soft rounded masses, a few more than 1 inch in diameter; few fine tubular pores; strong effervescence; moderately alkaline; gradual, smooth boundary.

C4g—48 to 55 inches, gray (5Y 5/1) silt loam; common, fine and medium, prominent, strong-brown (7.5YR 5/6) mottles; massive; friable; few fine tubular pores; common fine black concretions (oxides); common fine calcium carbonate accumulations in soft rounded masses; strong effervescence; moderately alkaline; gradual, smooth boundary.

C5g—55 to 76 inches, gray (5Y 5/1), olive-gray (5Y 5/2), and strong-brown (7.5YR 5/6) silt loam; few fine faint brown (7.5YR 4/4) mottles; massive; friable; few fine tubular pores; few thin discontinuous lenses of very fine sand; few, fine to medium, black concretions (oxides); few, fine to medium calcium carbonate accumulations in soft rounded masses; strong effervescence; moderately alkaline.

The A horizon ranges from heavy silt loam to light silty clay loam about 8 to 18 inches thick.

The Bg horizon ranges from very dark gray (10YR 3/1) to olive gray (5Y 5/2) or gray (5Y 5/1). It is heavy silt loam to silty clay loam.

Depth to the calcareous C horizon ranges from about 14 to 24 inches. In some places the C horizon is somewhat stratified. It is typically silty clay loam or silt loam, but in some places it is clay loam.

Secondary carbonates in soft rounded masses are common in the Bg horizon, in the upper part of the C horizon, and in a few places in the lower part of the C horizon. Reaction is neutral to mildly alkaline in the A horizon.

Wacousta soils differ from the Okoboji soils, which are also in upland depressions, in having lower clay content and gleyed horizons nearer the surface. Wacousta soils lack the gray A2 horizon that is characteristic of the Rolfe soils, which are in upland depressions. They generally have a thinner A horizon lower in sand content than the associated Webster and Canisteo soils. They lack the carbonates in the A horizon that are typical of Blue Earth soils. They also have a thinner A horizon than those soils.

506—Wacousta silty clay loam, 0 to 1 percent slopes. This nearly level soil is in the uplands in large depressions that were formerly shallow lakes. On the rims of the depression are the highly calcareous Harps soils and the calcareous Canisteo soils. Also associated in some areas are the Nicollet and Clarion soils.

Included with this soil in mapping are soils that are calcareous throughout. Also included are a few areas where the subsoil has been exposed by plowing and areas of soils that are deeper over the gleyed subsoil and resemble Okoboji soils.

This soil is naturally very poorly drained, and many areas are ponded in spring and after heavy rains. The subsoil is permeable enough for tile drains to function well where outlets are suitable. Open intakes to tile lines remove the surface water more quickly. In places shallow ditches are used.

Most of the acreage is artificially drained or partly drained and cultivated. This soil can be used much of the time for row crops. Growth is variable, depending upon how well the soil has been drained.

The seasonal high water table and ponding often damage crops and delay tillage, even if artificial drainage is installed. Some areas of this soil are managed separately, and some are managed with the adjacent soils. Capability unit IIIw-1, environmental planting group 2.

Wadena Series

The Wadena series consists of well drained soils on stream benches and glacial outwash areas. These soils formed under native prairie grasses in medium textured outwash underlain by calcareous sand and gravel at a depth of 32 to 40 inches. Slope is 0 to 3 percent.

In a representative profile the surface layer is black and very dark brown loam about 17 inches thick. The subsoil is loam and extends to a depth of about 37 inches. It is very dark grayish brown and dark brown in the upper part and brown and dark yellowish brown in the lower part. The substratum is yellowish brown and pale brown, loose, calcareous sand and gravel.

The Wadena soils have a moderate available water capacity. Permeability is moderately rapidly above the sand and gravel and rapid or very rapid in the sand and gravel. Available nitrogen is low, available phosphorus is very low, and available potassium is very low to low. The organic-matter content is moderate. The surface layer is neutral to slightly acid. These soils warm up quickly in spring and can be worked soon after rains.

Crops grown on these soils lack enough available water during periods of low rainfall. Runoff erodes the sloping soils if vegetation is sparse. If the soil is left bare, soil blowing is a hazard. Almost all the acreage is cultivated and is generally managed with the adjacent soils.

Representative profile of Wadena loam, deep, 0 to 3 percent slopes, 504 feet west and 36 feet north of southeast corner sec. 6, T. 96 N., R. 34 W.

Ap—0 to 7 inches, black (10YR 2/1) loam; cloddy parting to moderate, fine, granular structure; friable; common fine roots; few small pebbles; neutral; abrupt, smooth boundary.

A12—7 to 12 inches, black (10YR 2/1) loam; few very dark brown (10YR 2/2) peds in lower part; weak, fine, subangular blocky structure parting to moderate, fine, granular; friable; common fine roots; few small pebbles; neutral; clear, smooth boundary.

A3—12 to 17 inches, very dark brown (10YR 2/2) loam; few black (10YR 2/1) peds in upper part; weak, fine and medium, subangular blocky structure parting to moderate, fine, granular; friable; common fine roots; few small pebbles; neutral; gradual, smooth boundary.

B21—17 to 24 inches, very dark grayish-brown (10YR 3/2) and dark-brown (10YR 3/3) loam; few very dark brown (10YR 2/2) coats on faces of peds; weak, fine and medium, subangular blocky structure; friable; common fine roots; few small pebbles; neutral; gradual, smooth boundary.

B22—24 to 30 inches, brown (10YR 4/3) and dark yellowish-brown (10YR 4/4) loam; few dark yellowish-brown (10YR 3/4) coats on faces of peds; weak, medium, subangular blocky structure; friable; few fine roots; few fine inped tubular pores; common small and medium pebbles; few very fine dark-brown concretions (oxides); neutral; gradual, smooth boundary.

B3—30 to 37 inches, dark yellowish-brown (10YR 4/4) light loam; weak, medium, subangular blocky structure;

friable; few fine roots; few fine tubular pores; common fine and medium pebbles; few small rocks; few very fine dark-brown and black concretions (oxides); neutral; gradual, wavy boundary.

IIC—37 to 60 inches, yellowish-brown (10YR 5/4) and pale-brown (10YR 6/3) sand and gravel; single grained; loose; sand has clay bridging and is slightly cemented in places; few medium yellowish-red (5YR 4/6) and few fine dark-brown (7.5YR 4/4) concretions (oxides); slight effervescence; mildly alkaline.

The A horizon ranges from 7 to 18 inches thick. It ranges from black (10YR 2/1) to very dark grayish brown (10YR 3/2).

The B horizon is dark brown (10YR 3/3) to dark yellowish brown (10YR 4/4) in the upper part and is brown (10YR 4/3 to 7.5YR 4/4) to yellowish brown (10YR 5/4) in the lower part. It is typically loam, but in some places it ranges to gravelly loamy sand or sandy loam in the lower part.

The A and B horizons are typically neutral to slightly acid. The underlying calcareous sand and gravel is at a depth of 32 to 40 inches.

Wadena soils have a browner B horizon than the adjacent, somewhat poorly drained Cylinder soils. In contrast with the similar Estherville soils, they are deeper over calcareous sand and gravel and have less sand in the B horizon. Wadena soils are finer textured in the upper part of the profile and are more gravelly in the C horizon than Dickman soils, which are on similar landscapes.

308—Wadena loam, deep, 0 to 3 percent slopes. This nearly level to gently sloping soil is in outwash areas and on stream benches. It generally is with the Cylinder or Biscay soils. Individual areas are about 5 to 20 acres in size.

Included with this soil in mapping are areas where the depth to sand and gravel is more than 40 inches and some areas where slopes are about 4 or 5 percent.

This soil generally is cultivated. It is well suited to row crops. Crop growth is moderate to good under a high level of management. Soil blowing is a hazard if the soil is plowed in fall. This soil generally is managed with the adjacent soils. Capability unit I–2, environmental planting group 1.

Waldorf Series

The Waldorf series consists of poorly drained, nearly level soils in the uplands. These soils formed under prairie grasses in fine-textured lacustrine sediments.

In a representative profile the surface layer is black silty clay loam about 20 inches thick. The subsoil extends to a depth of about 45 inches. The upper 4 inches is black and very dark gray, firm silty clay loam. The lower part is dark grayish brown and olive gray silty clay that has olive and light olive brown mottles. The substratum is olive gray and light olive gray silty clay loam that has strong brown mottles.

The Waldorf soils have a high available water capacity and are moderately slowly to slowly permeable. Available nitrogen is generally low and available phosphorus and potassium are very low. The surface layer is generally neutral to slightly acid. The organic-matter content is high.

These soils are wet unless tile drained. Even when drained, they dry out slowly after rains and puddle easily if worked when wet. They are used for cultivated crops and are managed with the associated soils.

Representative profile of Waldorf silty clay loam, 0 to 2 percent slopes, 75 feet north and 1,640 feet west of southeast corner sec. 11, T. 95 N., R. 34 W.

Ap—0 to 8 inches, black (10YR 2/1) silty clay loam; cloddy parting to moderate, granular structure; firm; common fine roots; very few fine strong-brown concretions (oxides); neutral; abrupt, smooth boundary.

A12—8 to 14 inches, black (10YR 2/1) silty clay loam; few, fine, faint, very dark gray (10YR 3/1) mottles; weak, fine, subangular blocky structure parting to moderate, very fine and fine, granular; firm; common fine roots; very few fine dark-brown concretions (oxides); neutral; gradual, smooth boundary.

A3—14 to 20 inches, black (10YR 2/1) silty clay loam; few, fine, faint, very dark gray (10YR 3/1) mottles; weak, very fine, subangular blocky and moderate, fine, granular structure; firm; common fine roots; very few very fine dark-brown concretions (oxides); neutral; gradual, smooth boundary.

B1—20 to 24 inches, black (10YR 2/1) and very dark gray (10YR 3/1) silty clay loam; common, fine, faint, dark grayish-brown (10YR 4/2) mottles; moderate, very fine, subangular blocky and moderate, fine, granular structure; firm; few fine roots; few fine tubular pores; few thin discontinuous clay films; neutral; clear, smooth boundary.

B21—24 to 35 inches, dark grayish-brown (2.5Y 4/2) and olive-gray (5Y 4/2) silty clay, dark grayish brown (10YR 4/2) kneaded; very dark gray (10YR 3/1) and very dark grayish-brown (2.5Y 3/2) coatings on faces of peds; few, fine, faint, olive-gray (5Y 5/2) mottles; weak, medium, prismatic structure parting to moderate, very fine, granular; firm; few fine roots; fine tubular pores; common thin and medium continuous clay films; common fine dark-brown concretions (oxides); neutral; gradual, smooth boundary.

B22g—35 to 45 inches, olive-gray (5Y 5/2) light silty clay; dark-gray (5Y 4/1) coatings on faces of peds; common, fine, faint, olive (5Y 5/3) and light olive-brown (2.5Y 5/4) mottles; weak, medium, prismatic structure parting to moderate, fine, subangular blocky; firm; few fine roots; few fine tubular pores; common thin and medium continuous clay films; common fine dark-brown concretions (oxides); neutral; gradual, smooth boundary.

C1g—45 to 57 inches, olive-gray (5Y 5/2) and light olive-gray (5Y 6/2) heavy silty clay loam; olive-gray (5Y 4/2) and dark gray (5Y 4/1) coatings on faces of peds; common, fine, distinct, strong-brown (7.5YR 5/6) mottles; weak, medium, prismatic structure parting to weak, coarse, subangular blocky; firm; common thin and medium continuous clay films; many fine brown and black concretions (oxides); slight effervescence; mildly alkaline; gradual, smooth boundary.

C2g—57 to 65 inches, olive-gray (5Y 5/2) silty clay loam; common, fine, prominent, strong-brown (7.5YR 5/8) mottles; few dark-gray (5Y 4/1) fills in old root channels; massive; strong effervescence; moderately alkaline.

The A horizon ranges from black (N 2/0 or 10YR 2/1) to very dark gray (N 3/0 or 10YR 3/1). It is generally 16 to 24 inches thick.

The B horizon is typically silty clay loam or light silty clay. In some places it is heavy clay loam. It ranges from dark grayish brown (2.5Y 4/2) to olive gray (5Y 4/2 to 5/2). In some places it is olive (5Y 5/3). The solum is 30 to 48 inches thick.

The C horizon is grayish brown (2.5Y 5/2) to olive-gray (5Y 5/2), calcareous, stratified silty clay or silty clay loam sediments. Yellowish brown, strong brown, light olive brown, and olive mottles are common.

The Waldorf soils are more clayey and have less sand in the profile than the Webster soils on similar landscapes.

These soils are poorly drained. In contrast with Talcot and Biscay soils, they do not have sand and gravel in the C horizon.

390—Waldorf silty clay loam, 0 to 2 percent slopes. This nearly level soil is in the uplands and in outwash areas. In the uplands it occurs with Webster and Canisteo soils and in outwash areas with Biscay, Cylinder, and Talcot soils. Slopes are generally concave, but in a few places they are slightly convex.

Included with this soil in mapping are a few areas where drainage is better and the subsoil is browner. Also included are a few spots that are slightly calcareous. In places glacial till is at a depth of about 40 to 50 inches.

Most of the acreage is cultivated. Row crops can be grown most of the time, but in wet years crop growth is generally only moderate. Because the fine-textured subsoil restricts the movement of air and water, the soil is cold and wet late in spring. Tile drains do not function well. They should be spaced closer than in coarser textured soils. If this soil is plowed when wet, it tends to be cloddy and hard when dry.

A good seedbed generally is easier to prepare if the soil is plowed in fall. Areas of this soil are managed with the adjacent soils, except for one or two areas near Ayrshire that are large enough to be managed separately. Capability unit IIw–1, environmental planting group 2.

Watseka Series

The Watseka series consists of somewhat poorly drained, nearly level soils. These soils formed under native vegetation of prairie grasses in coarse textured alluvium on low stream benches.

In a representative profile the surface layer is very dark brown loamy fine sand in the upper part and very dark grayish brown loamy fine sand in the lower part. It is about 13 inches thick. The subsoil extends to a depth of about 39 inches. The upper part is very dark grayish brown and dark brown, and the lower part is mixed dark yellowish brown, grayish brown, and light brownish gray to dark brown and strong brown. The texture is loamy fine sand that grades to fine sand. Iron bands and streaks are common. The substratum is grayish brown, dark yellowish brown, and yellowish brown medium sand and fine sand mottled with yellowish red and strong brown.

The Watseka soils have low available water capacity and are rapidly permeable. Available nitrogen, phosphorus, and potassium are very low. The surface layer and subsoil are typically slightly acid to medium acid. The organic-matter content is low. These soils warm up quickly in spring, and they can be worked soon after rains. They are subject to soil blowing if the surface is left bare or if vegetation is sparse.

These soils are used mainly for cultivation. They are poorly suited to row crops, because they are droughty and subject to severe soil blowing. Many areas are low enough that they are flooded in some years. Flooding generally occurs, however, early in spring and does not seriously affect use or management.

Representative profile of Watseka loamy fine sand, 0 to 2 percent slopes, 90 feet north and 62 feet west of southeast corner sec. 27, T. 94 N., R. 31 W.

Ap—0 to 8 inches, very dark brown (10YR 2/2) loamy fine sand, dark grayish brown (10YR 4/2) dry; weak, fine, subangular blocky structure parting to weak, fine and very fine, granular; very friable; common fine roots; slightly acid; abrupt, smooth boundary.

A3—8 to 13 inches, very dark grayish-brown (10YR 3/2) loamy fine sand, mixed with very dark brown (10YR 2/2) in upper part; few, fine, faint, dark yellowish-brown (10YR 4/4) mottles; weak, very fine, prismatic and weak, fine, subangular blocky structure parting to weak, fine, granular; very friable; common fine roots; medium acid; clear, smooth boundary.

B1—13 to 18 inches, very dark grayish-brown (10YR 3/2) and dark-brown (10YR 3/3) loamy fine sand; common, fine, faint, dark grayish-brown (10YR 4/2) mottles; weak, medium, prismatic structure parting to weak, fine and medium, subangular blocky; very friable; few fine roots; medium acid; gradual, smooth boundary.

B2—18 to 26 inches, dark yellowish-brown (10YR 4/4), very dark grayish-brown (10YR 3/2), and grayish-brown (10YR 5/2) loamy fine sand; some strong-brown (7.5YR 5/6) elongated stains; common, fine, distinct, yellowish-brown (10YR 5/4) mottles; weak, fine, prismatic structure parting to weak, fine, subangular blocky; very friable; few fine roots; few small pebbles; few fine manganese and common fine iron concretions (oxides); medium acid; gradual, smooth boundary.

B31—26 to 33 inches, grayish-brown (2.5Y 5/2), light brownish-gray (2.5Y 6/2), brown (10YR 4/3), and dark yellowish brown (10YR 4/4) loamy fine sand; common strong-brown (7.5YR 5/6) stains; weak, fine and very fine, prismatic structure parting to weak, fine, subangular blocky; very friable; few small pebbles; some thin clay coatings on sand grains and some clay bridging between grains; few fine manganese and iron concretions (oxides); medium acid; gradual, smooth boundary.

B32—33 to 39 inches, grayish-brown (2.5Y 5/2), dark-brown (7.5YR 4/4), and strong-brown (7.5YR 5/6 and 7.5YR 5/8) fine sand; few, fine, prominent, yellowish-red (5YR 4/6) mottles; weak, fine, subangular blocky structure parting to single grained; very friable to loose; few small pebbles; thin clay coatings of sand grains and some clay bridging between grains; few fine dark-brown concretions (oxides); slightly acid; gradual, smooth boundary.

C1—39 to 49 inches, grayish-brown (2.5Y 5/2), dark yellowish-brown (10YR 4/4), and yellowish-brown (10YR 5/6 and 5/8) medium sand; few, fine, prominent, yellowish-red (5Y 4/6) mottles; single grained; loose; few small pebbles; few fine dark-brown concretions (oxides); few fine manganese and iron concretions (oxides); slightly acid; clear, smooth boundary.

C2—49 to 65 inches, grayish-brown (2.5Y 5/2) fine sand; common, medium, distinct, strong-brown (7.5YR 5/6) mottles; single grained; loose; few fine manganese and iron concretions (oxides); slightly acid.

The A horizon is 8 to 20 inches thick and is very dark brown (10YR 2/2), very dark gray (10YR 3/1), or very dark grayish brown (10YR 3/2). It is typically medium or coarse loamy sand, but in some places it is sandy loam. A small amount of very coarse sand and small gravel particles is evident in some places.

The B1 horizon is loamy fine sand or sandy loam in most places. It is very dark grayish brown (10YR 3/2) and dark brown (10YR 3/3) to brown (10YR 4/3). The B2 horizon is typically loamy fine sand, but it is loamy medium sand or fine and medium sand in some places. It is dominantly dark yellowish brown (10YR 4/4), grayish brown

(10YR 5/2 to 2.5Y 5/2), and light brownish gray (2.5Y 6/2). The B3 horizon is loamy fine sand or fine or medium sand. It is grayish brown (10YR 5/2 to 2.5Y 5/2) and dark brown (7.5YR 4/4) to strong brown (7.5YR 5/6 to 5/8). It is commonly about 10 to 15 percent coarse sand or fine gravel.

The C horizon is grayish-brown (2.5Y 5/2 to 10YR 5/2) to light brownish-gray (2.5Y 6/2) fine, medium, or coarse sand. Mottles and part of the matrix color are dark yellowish brown (10YR 4/4 to strong brown (10YR 5/8). Mottles of redder hue are also in the range, but typically are few or common in number. Reaction is slightly acid or medium acid throughout.

The Watseka soils are somewhat coarser textured and have a grayer B horizon than the Dickman soils. They do not have the gravelly C horizon that is typical of Estherville and Salida soils, and they are not calcareous in the solum, which is typical of Salida soils. Watseka soils are associated with Estherville soils on the landscape and formed in parent material similar in texture, except for the gravel content, to that of Dickman and Salida soils.

141—Watseka loamy fine sand, 0 to 2 percent slopes. This nearly level soil is on low stream benches. It occurs mainly with Biscay, Cylinder, Estherville, Hanska, and Flagler soils. Slopes are plane to slightly convex. Individual areas are typically about 30 acres in size.

Included with this soil in mapping were a few areas where the surface layer is fine sandy loam or loamy sand. Also included were a few areas of soils that have a small amount of very coarse sand and fine gravel throughout the profile.

Most of the acreage is cultivated. Some areas are used for hay crops and rotation pasture. This soil is suited to row crops, but droughtiness and soil blowing are serious hazards. The soil dries quickly after rains. Blowing sand often damages young plants. Crops growth is poor, especially in years when rainfall is below average or rains are not timely.

Minimum tillage and crop residue on the surface conserve moisture and reduce the hazard of soil blowing. Most of the acreage is flooded for short periods during periods of high water, but flooding seldom hinders its use. This soil is managed with the adjacent soils. Capability unit IIIs–1, environmental planting group 4.

Webster Series

The Webster series consists of nearly level, poorly drained soils. These soils formed in the uplands under native marsh grasses and sedges in glacial till or sediments from till.

In a representative profile the surface layer is black silty clay loam that is sandy enough to have a gritty feel. It is about 17 inches thick. The subsoil extends to a depth of about 48 inches. It is olive gray, firm clay loam. It has yellowish brown and strong brown mottles. The substratum is gray, friable, massive, calcareous clay loam till. It has strong brown mottles. These soils are typically neutral in the surface layer and mildly akaline in the upper part of the subsoil to moderately alkaline in the lower part and in the substratum.

Webster soils have a high available water capacity and are moderately permeable or moderately slowly permeable. They have a high water table. Available nitrogen is medium to low, and available phosphorus and available potassium are very low to low. The surface layer is typically neutral; no lime is needed. The organic-matter content is high. Runoff from soils upslope collects on some areas of these soils after heavy rains.

Webster soils are wet unless tile drained. Even when drained, they dry out slowly after rains and puddle easily if worked when wet. Nearly all the acreage in this county is artificially drained and is cultivated. Areas plowed in fall are subject to soil blowing unless protected. Some areas are large enough to be managed separately, but most areas are managed with the associated soils.

Representative profile of Webster silty clay loam, 0 to 2 percent slopes, 78 feet west and 700 feet south of northeast corner SE¼ sec. 5, T. 97 N., R. 32 W.

Ap—0 to 8 inches, black (N 2/0) silty clay loam; cloddy breaking to moderate, fine, granular structure; friable; neutral; abrupt, smooth boundary.

A12—8 to 17 inches, black (N 2/0) silty clay loam; moderate, fine, subangular blocky structure parting to moderate, fine, granular; firm; neutral; gradual, smooth boundary.

B1—17 to 23 inches, black (10YR 2/1), dark grayish-brown (2.5Y 4/2), and 25 percent very dark gray (10YR 3/1) clay loam; moderate, fine, subangular blocky structure; firm; neutral; gradual, smooth boundary.

B21g—23 to 30 inches, olive-gray (5Y 5/2) clay loam; common black (10YR 2/1) and very dark gray (10YR 3/1) coats on faces of peds, the number decreasing with increasing depth; few, fine, distinct, yellowish-brown (10YR 5/6) mottles; weak, fine and medium, subangular blocky structure; firm; common, 3- to 4-millimeter, black concretions (oxides); neutral; clear, smooth boundary.

B22g—30 to 36 inches, olive-gray (5Y 5/2) clay loam; mottles are common fine distinct yellowish brown (10YR 5/6) and few fine distinct strong brown (7.5YR 5/6); weak, medium, subangular blocky structure; firm; common fine black and few strong-brown concretions (oxides); few dark worm casts; few calcium carbonate accumulations in soft rounded masses; mildly alkaline; gradual, smooth boundary.

B3g—36 to 48 inches, olive-gray (5Y 5/2) clay loam; few gray (5Y 5/1) coats on faces of peds; mottles are common fine distinct yellowish brown (10YR 5/6) and few fine distinct strong brown (7.5YR 5/6); weak, medium, subangular blocky structure in upper part grading to massive in lower part; friable; common fine black and few strong-brown concretions (oxides); few dark worm casts; few calcium carbonate accumulations in soft rounded masses; slightly effervescent; mildly alkaline; diffuse, smooth boundary.

Cg—48 to 60 inches, gray (5Y 5/1) clay loam; many, fine, prominent, strong-brown (7.5YR 5/6) mottles; massive; friable; common fine black and few strong-brown concretions; few dark worm casts; few calcium carbonate accumulations in soft rounded masses; slight effervescence; mildly alkaline.

Webster soils are black (N 2/0 or 10YR 2/1) in the A1 horizon and very dark gray (N 3/0 or 10YR or 5Y 3/1) in the A3 horizon. The A horizon is silty clay loam with a noticeable amount of sand or clay loam. It is about 16 to 24 inches thick.

The B1 horizon is black (10YR 2/1), very dark gray (10YR 3/1), or very dark grayish brown (2.5Y 3/2). The B2g horizon is dark gray (5Y 4/1), gray (5Y 5/1), or olive gray (5Y 4/2 to 5/2). In some pedons, parts of the B2 and B3 horizons are dark grayish brown (2.5Y 4/2) or grayish brown (2.5Y 5/2). The B horizon is silty clay loam with a noticeable amount of sand or clay loam.

The C horizon is similar to the B2 horizon in color, but is light olive gray (5Y 6/2) to olive (5Y 5/8) in places.

Webster soils are typically neutral in reaction. The depth

to carbonates is typically 24 to 36 inches, but ranges to about 48 inches.

Webster soils are grayer in the B horizon than Nicollet soils. They have a thinner A horizon than Okoboji soils. They lack the high carbonate content typical of Canisteo and Harps soils. All are associated on the landscape.

107—Webster silty clay loam, 0 to 2 percent slopes. This nearly level soil is on the undulating till plain and in irregularly shaped, concave upland swales and draws. It is adjacent to Okoboji soils, which are in distinct depressions. It is also adjacent to Canisteo soils in places and is downslope from Clarion and Nicollet soils. The size and shape of areas vary widely. In the eastern two-thirds of the county, many areas are large and fairly broad, but in the western third, most areas are long and fairly narrow. Areas range from about 5 to 80 acres in size.

Included with this soil in mapping were a few areas where the subsoil has about a 6-inch layer of silty clay between depths of 2 and 3 feet. Also included were a few areas where the substratum below 3 feet is fine sand or loamy sand and in sections 21, 27, and 28 of West Bend Township, several large areas, adjacent to Truman soils where the soil is low in sand and has a smooth feel. Identified by spot symbols on the soil map are areas one-half acre or less of Clarion soils, the depressional Rolfe soils, the highly calcareous Harps soils, and the depressional Okoboji soils. All but the included areas of Okoboji soils are distinctly lighter in color when dry.

This soil is used mostly for row crops. If adequately drained, it is well suited (fig. 21). Tile drains function well. If plowed when wet, the soil puddles easily and becomes cloddy and hard to work when dry. Plowing in fall is a common practice because the clods are broken during periods of freezing and thawing. Soil blowing, however, is a hazard if large areas are plowed in fall and the surface is left bare. A few areas where drainage has not been improved are in permanent pasture. A few areas are managed separately, but most areas are managed with the surrounding soils. Capability unit IIw–1, environmental planting group 2.

Use and Management of the Soils

This section is designed to help the landowner understand how soils respond and how they can be used. It

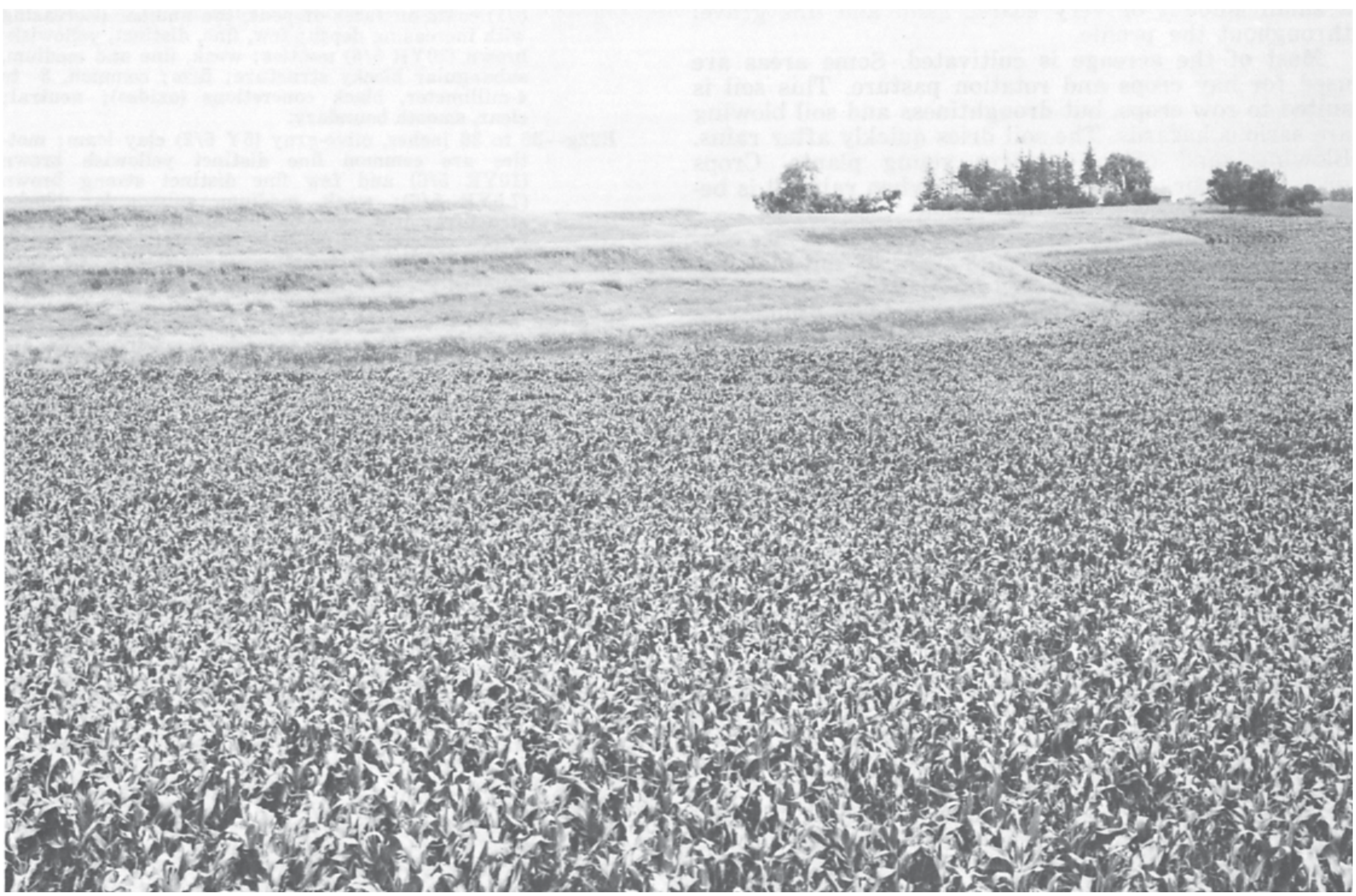

Figure 21.—**Corn on Webster silty clay loam, 0 to 2 percent slopes, in foreground. The intake terraces on the Clarion and Storden soils in the background remove excess water through an underground tile system and prevent it from running on the lower lying Webster soils.**

explains how the soils can be used and managed for crops and pasture, environmental plantings, wildlife, and engineering works.

Crops and Pasture

About 73 percent of Palo Alto County, or 262,516 acres, is used for crops. About 5 percent, or 17,836 acres, is used for pasture.

Corn, soybeans, alfalfa, and alfalfa-grass hay are the main crops. Oats and sorghum are also grown.

Most pastures are in permanent bluegrass. Some have been renovated and are in bromegrass or orchardgrass or a mixture of these grasses with alfalfa.

Some soils in the county, including Clarion and Storden soils, are subject to sheet erosion and gullying. Grassed backslope terraces and contour tillage are commonly used for erosion control. Grassed waterways and in places farm ponds control gullying. The farm ponds also furnish water for recreation and livestock.

Because of the intensity of rowcropping, all soils in the county are subject to soil blowing, especially when plowed in fall. Blowing is especially a hazard on Estherville, Salida, Linder, Dickman, Farrar, Flagler, and Watseka soils, all of which have a low available water capacity. It is also a hazard on soils having a coarse or moderately coarse surface layer that dries quickly.

Drain tiles are used in Blue Earth, Calco, Canisteo, Colo, Harps, Mayer, Okoboji, Palms, Rolfe, Talcot, Webster soils, and other soils with restricted drainage. In many places drainage ditches are constructed mainly to serve as outlets for drainage tile. Shallow ditches and surface tile intakes remove excess surface water from depressional soils. In a few places levees have been constructed to protect soils on the bottom lands from flooding. In a few places in the county streams have been straightened to reduce the hazard of flooding.

Capability grouping

Capability classification is the grouping of soils to show, in a general way, their suitability for most kinds of farming (*15*). It is a practical classification based on the limitations of the soils, the risk of damage when they are used for ordinary field crops or sown pastures, and the way they respond to treatment. The classification does not apply to horticultural crops, or to rice and other crops that have their own special requirements for economical production. The soils are classified according to degree and kind of permanent limitations, but without consideration of major and generally expensive landforming that would change slope, depth, or other characteristics of the soils, and without consideration of possible major reclamation. A complete discussion of the capability classification is given in Agriculture Handbook 210, Land Capability Classification (*15*).

In the capability system, all the soils are grouped at three levels, the capability class, the subclass, and the unit. These levels are described in the following paragraphs.

CAPABILITY CLASSES, the broadest grouping, are designated by Roman numerals I through VIII. As the numerals increase, they indicate progressively greater limitations and narrower choices for practical use. The classes are defined as follows:

Class I soils have few limitations that restrict their use.

Class II soils have some limitations that reduce the choice of plants or require moderate conservation practices.

Class III soils have severe limitations that reduce the choice of plants, require special conservation practices, or both.

Class IV soils have very severe limitations that restrict the choice of plants, require very careful management, or both.

Class V soils are subject to little or no erosion but have other limitations, impractical to remove, that limit their use largely to pasture or range, woodland, or wildlife food and cover.

Class VI soils have severe limitations that make them generally unsuited to cultivation without major reclamation and that limit their use largely to pasture or range, woodland, or wildlife food and cover.

Class VII soils have very severe limitations that make them unsuited to cultivation without major reclamation and that restrict their use largely to range, woodland, or wildlife food and cover.

Class VIII soils and landforms have limitations that preclude their use for commercial plant production without major reclamation and that restrict their use to recreation, wildlife, or water supply or to esthetic purposes. (None in Palo Alto County.)

CAPABILITY SUBCLASSES are soil groups within one class. They are designated by adding a small letter, *e, w, s,* or *c,* to the class numeral, for example, IIe. The letter *e* shows that the main limitation is risk of erosion; *w* shows that water on or in the soil interferes with plant growth or cultivation; *s* shows that the soil is limited mainly because it is shallow, droughty, or stony; and *c,* used in some parts of the United States, but not in Iowa, shows that the chief limitation is climate that is too cold or too dry.

CAPABILITY UNITS are soil groups within the subclasses. The soils in one capability unit are enough alike to be suited to the same crops and pasture plants to require similar management, and to have similar productivity and other responses to management. Capability units are generally designated by adding an Arabic numeral to the subclass symbol, for example, IIe-1 or IIIs-3.

The capability classification of each soil in Palo Alto County is given in the "Guide to Mapping Units" at the end of this survey.

Management of soils by capability units

On the following pages, the capability units, or groups of soils that have similar management requirements, are described; limitations are mentioned; and

suitable management is suggested. To find the names of all the soils in any given capability unit, refer to the "Guide to Mapping Units" in the back of the survey. The practical grouping of soils shown in this guide are subject to change as new methods are discovered or new information becomes available.

CAPABILITY UNIT I-1

This unit consists of nearly level, somewhat poorly drained loamy soils and nearly level, well-drained silty soils on uplands. These soils have a loam or silt loam surface layer and a light clay loam or silt loam subsoil.

These soils are high in available water capacity and are moderately permeable. They have high organic-matter content. Reaction is typically neutral or slightly acid in the surface layer and upper part of the subsoil, but in places it is mildly alkaline in the surface layer and moderately alkaline in the subsoil. Available nitrogen is low to medium, and available phosphorus and potassium are very low to low.

The soils are used mostly for cultivated crops. They are well suited to row crops. Corn and soybeans are the major crops, but oats and hay are important. An occasional green-manure crop is grown.

In most areas these soils are wet when rainfall is above average and fieldwork is delayed. Most of these soils, however, are farmed without any artificial drainage. Although erosion is ordinarily not a hazard, contour farming is desirable on long slopes where row-cropping is intensive.

Crops respond well to fertilization. Soils that have a mildly alkaline surface layer require somewhat larger additions of phosphorus and potassium than the neutral or slightly acid soils. Lime is needed in some areas of slightly acid soils.

CAPABILITY UNIT I-2

This unit consists of nearly level, well drained and somewhat poorly drained loamy soils on stream benches. These soils have a friable loam surface layer and subsoil and are underlain by sand and gravel at a depth of about 36 inches.

These soils are moderately or moderately rapidly permeable in the upper part and rapidly permeable to very rapidly permeable in the underlying sand and gravel. They have moderate available water capacity. The organic-matter content is moderate to high. Reaction is typically neutral to slightly acid, but in places it is mildly alkaline just above the sand and gravel. Available nitrogen is low, available phosphorus is very low, and available potassium is very low to low. The sand and gravel restricts root development to some extent and also influences the available water capacity. These soils, especially the well-drained soils, tend to be somewhat droughty. During wet periods the somewhat poorly drained soils are wet, but drainage is seldom needed.

Most areas of these soils are cultivated. Row crops are well suited. Corn and soybeans are the main crops, but oats and hay are also grown. Conserving moisture and reducing soil blowing are especially beneficial on the well-drained soils. Because the soils have only moderate available water capacity, a reduction in the number of corn plants is sometimes needed.

Crops respond well to fertilization. Lime is generally needed on the slightly acid soils.

CAPABILITY UNIT IIe-1

This unit consists mainly of deep, gently sloping, somewhat excessively drained or well drained soils on uplands. These soils have a loam or silt loam surface layer and subsoil. Some soils in this unit are excessively drained, have a loam or sandy loam surface layer and a sandy loam subsoil, and are only about 2 feet over sand and gravel. One soil is on foot slopes and is somewhat poorly drained. During very wet periods it is wet. Drainage, however, is seldom needed.

Most soils in this unit are moderately permeable. Some are moderately rapidly permeable in the upper part and very rapidly permeable in the lower part. Most have high available water capacity. Some have a low capacity, or seldom reach capacity because they have excessive runoff or because they are only 2 feet deep over sand and gravel, which not only severely limits the amount of water available, but also limits root development. Most of the soils are high or moderate in organic-matter content, but some are low. Most are neutral to slightly acid, but some are neutral to mildly alkaline, and a few are medium acid. Available nitrogen, phosphorus, and potassium are generally very low to low.

Most areas of these soils are cultivated. Corn and soybeans are the major crops, but oats and crops for rotation hay and pasture are also commonly grown. Water erosion is a hazard. Soil blowing is a hazard also, especially on the soils underlain by sand and gravel. Terraces and contour tillage are needed for control of erosion and runoff. Terraces are difficult to establish in places because of the size and the shape of the areas and the irregular slopes. Diversion terraces are needed on some foot slopes to carry runoff from adjacent slopes. If erosion is controlled, all but the droughty soils are well suited to row crops. The soils that have low available water capacity and are droughty are better suited to forage production.

Crops respond well to fertilization. Lime is generally needed on the neutral to slightly acid soils.

CAPABILITY UNIT IIw-1

This unit consists of loamy, mainly nearly level, poorly drained and very poorly drained soils on uplands. These soils have a deep, dark silty clay loam surface layer and a silty clay, clay loam, or silty clay subsoil.

These soils are moderately permeable, moderately slowly permeable, or slowly permeable. They have high available water capacity. The organic-matter content is high. Available nitrogen is medium or low, and available phosphorus and potassium are very low to low. The soils are wet unless artificially drained. A seasonal high water table is generally at a depth of about 3 feet or less. Runoff is slow on most areas. Water tends to pond in slightly depressed areas during periods of high rainfall. These soils are slow to warm up in spring and tend to dry out cloddy and hard if worked when

wet. They are often plowed in fall so that the freezing and thawing will improve soil tilth and allow more timely fieldwork in spring.

Most areas of these soils are cultivated. Corn and soybeans are the major crops. Oats and hay are grown occasionally. These soils are well suited to row crops if adequately drained. Tile drains function well, but a somewhat closer spacing of tile lines is needed where the subsoil is silty clay. The soils that are high in lime need somewhat greater additions of phosphorus and potassium.

Crops respond well to fertilization. Some areas need lime.

CAPABILITY UNIT IIw-2

This unit consists of nearly level or gently sloping, poorly drained or moderately well drained to somewhat poorly drained loamy soils mainly on the bottom lands.

These soils are deep and moderately slowly permeable or moderately permeable. They have high available water capacity. The organic-matter content is high. Available nitrogen is medium to low, available phosphorus is very low to medium, and available potassium is very low to low. Most of the soils are wet unless artificially drained, but those that have a loam surface layer and are moderately well to somewhat poorly drained are usually farmed without artificial drainage. Most areas are subject to some flooding, but this generally occurs early in spring or is of short duration. Some areas are subject to runoff from adjacent slopes. These soils are slow to warm up in spring. The soils that have a silty clay loam surface layer tend to dry out cloddy and hard if worked when wet.

Many areas are cultivated, but many are in permanent pasture. Corn and soybeans are the major crops. Other crops are seldom grown. The soils are well suited to row crops. Drainage and protection from flooding improve the timeliness of fieldwork and also increase yields. Tile drains are used. Many areas, however, are farmed without supplemental drainage. In places suitable outlets for tile drains are not available.

The soils that are in narrow drainageways are associated with steep soils, and many of these are in permanent pasture. Small meandering streams cut many areas and thus limit their use for cultivated crops. By straightening these channels, the hazard of flooding can be reduced. Most areas receive runoff from adjacent slopes, and in places gullies have formed. Diversion terraces are needed to control runoff and prevent erosion. Tile drains are needed. Contour tillage is needed to reduce the slight erosion caused by surface runoff on the soils on foot slopes.

Crops respond well to fertilization. Most of the soils are neutral to slightly acid, and some need lime. Others are calcareous and contain excess lime.

CAPABILITY UNIT IIw-3

Harps loam, 0 to 2 percent slopes, the only soil in this unit, is nearly level, poorly drained, and high in lime. It typically occurs on the narrow rims of depressions that are occupied by soils of other capability units. The surface layer is friable loam. The subsoil is clay loam that is moderately permeable.

The available water capacity is high. The organic-matter content is high. Reaction is moderately alkaline. Available nitrogen is low, and available phosphorus and potassium are very low. This soil is poorly drained and is wet unless artificially drained. A seasonally high water table is at a depth of 3 feet or less. Because this soil is adjacent to depressional soils that are frequently flooded during periods of high rainfall, tillage is sometimes delayed.

Most areas are cultivated. Corn and soybeans are the main crops, but oats and hay crops are sometimes grown. This soil is well suited to row crops. Tiles are needed to improve soil aeration and the timeliness of fieldwork. Tiles function well. Available phosphorus and potassium are lower in this soil than in some of the adjacent soils, because of the excess lime and poor drainage. Therefore, larger additions of both nutrients are needed. Soybean leaves commonly turn yellow when the plants are only a few inches high because of a lack of an adequate amount of available iron. This condition can be overcome by spraying the leaves with a solution of ferrous sulfate or other iron compounds. Some varieties of soybeans are less susceptible than others to this condition.

Crops respond well to fertilization. No lime is needed.

CAPABILITY UNIT IIw-4

This unit consists of loamy, nearly level, poorly drained soils in areas of glacial outwash and on stream benches. These soils have a deep, dark, friable loam surface layer and a sandy loam subsoil and are only about 30 inches deep over sand and gravel.

These soils are moderately permeable or moderately rapidly permeable in the upper part and rapidly permeable to very rapidly permeable in the underlying sand and gravel. They have moderate to low available water capacity. The organic-matter content is high. Reaction is neutral to moderately alkaline. Available nitrogen is medium to low, and available phosphorus and potassium are very low. The sand and gravel beneath these soils restricts root development to some extent and influences the available water capacity. These soils have a seasonal high water table. Some areas flood during periods of high rainfall. Although poorly drained, they are somewhat droughty, especially when rainfall is below average or is not timely.

Some areas are cultivated. Where drainage has not been improved the soils are pastured or idle. If adequately drained, these soils are well suited to row crops. Corn and soybeans are the main crops, but oats and hay crops are also grown. Drainage improvement and flood protection improve the timeliness of fieldwork. Tile drains function well. Suitable outlets, however, are not available in places. Care is needed to avoid overdrainage. If fields are plowed in fall and the surface is left bare, severe soil blowing is likely. Preventing soil blowing and conserving moisture are especially needed on these soils.

Crops respond well to fertilization in most years. Some soils are moderately alkaline and require larger additions of phosphorus and potassium than others. Lime is seldom needed.

CAPABILITY UNIT IIw-5

This unit consists of nearly level, poorly drained soils in outwash areas and on stream benches. These soils have a deep, dark clay loam or loam surface layer and similar texture in the subsoil. They are underlain by calcareous sand and gravel.

These soils are moderately permeable above the sand and gravel and rapidly permeable or very rapidly permeable in the sand and gravel. They have moderate available water capacity. The organic-matter content is high. Reaction is neutral to moderately alkaline. Available nitrogen is medium to low, available phosphorus is very low, and available potassium is very low to low. The underlying sand and gravel restricts root development to some extent and influences the available water capacity. These soils are wet unless artificially drained. A few areas are flooded during periods of high rainfall. Flooding generally occurs early in spring and in most years does not seriously affect cropping. The soils warm slowly in spring and tend to dry out cloddy and hard if worked when wet. They are often plowed in fall so that the freezing and thawing will improve soil tilth and allow more timely fieldwork in spring. Soil blowing is a hazard, however, where large areas are left bare.

Most areas of these soils are cultivated. Corn and soybeans are the main crops, but oats and hay crops are also grown. Some areas are in permanent pasture. These soils are well suited to row crops if drainage is adequate and the hazard of flooding is not too great. Tile drains are used. Care is needed to avoid overdraining areas that are moderately deep to sand and gravel. Although some undrained areas are cultivated, they are better suited to hay and pasture plants.

Grassed waterways are needed in some places. Open ditches are used as outlets for tile drains in places. When these soils are plowed in fall, leaving crop residue on the surface and alternating plowed and unplowed strips help to reduce soil blowing.

Crops respond well to fertilization. Some soils are moderately alkaline and require larger additions of phosphorus and potassium than others. Lime is not needed.

CAPABILITY UNIT IIs-1

Linder loam, 0 to 2 percent slopes, is the only soil in this unit. It is a nearly level, somewhat poorly drained loamy soil on stream benches and in outwash areas. It has a friable loam surface layer and a sandy loam subsoil. It is underlain by sand and gravel at a depth of 24 to 30 inches.

This soil has low available water capacity and is droughty. The organic-matter content is moderate. Reaction is neutral to slightly acid. Available nitrogen is low, available phosphorus is very low, and available potassium is very low. The soil is moderately rapidly permeable in the upper part and rapidly to very rapidly permeable in the sand and gravel substratum. The sand and gravel beneath this soil restricts root development to some extent and influences the available water capacity. Soil blowing is a hazard.

Most areas are used for cultivated crops, but a few are in permanent pasture. Cultivated areas are used for corn, soybeans, oats, and hay crops. Row crops are well suited, but protection is needed against soil blowing. Production of forage crops is a better alternate use on these soils. Grain sorghum can be grown instead of corn. Minimum tillage and crop residue on the surface help conserve moisture and reduce the hazard of soil blowing. Alternate strips of hay crops and row crops are beneficial when these soils are being prepared for planting. If row crops, particularly corn, are grown, the final stand needs to be reduced somewhat because of a lack of adequate available water. Maintaining organic-matter content and soil tilth are important.

Crops respond well to fertilization when rainfall is above normal, but the response is only moderate in other years. This soil is neutral to slightly acid. Some areas need additions of lime.

CAPABILITY UNIT IIIe-1

This unit consists of moderately sloping, well-drained or somewhat excessively drained soils on uplands. These soils have a friable, medium-textured surface layer and subsoil or substratum.

These soils are moderately permeable and have a high available water capacity. Organic-matter content is low to moderate, depending on past erosion. Reaction ranges from slightly acid to mildly alkaline in the surface layer and from slightly acid to moderately alkaline in the subsoil or substratum. Available nitrogen is very low to low, and available phosphorus and potassium are very low to low. These soils are subject to runoff and erosion, especially during periods of heavy rainfall. Soil tilth is generally good. Eroded areas generally have somewhat poorer tilth than other areas.

Most areas are cultivated, but a few are pastured, mainly around the farmstead. Corn, soybeans, oats, and meadow are the main crops. These soils are subject to erosion. They are moderately suited to row crops if erosion is controlled.

The major management need is erosion control. Terraces and contour tillage are generally used.

In some places terraces are difficult to establish because of the size and the shape of the areas and the irregular slopes. Grassed waterways are used in places. Maintaining organic-matter content, soil tilth, and fertility is important.

Crops respond well to fertilization. Because some of the soils are alkaline and very low in available nitrogen, phosphorus, and potassium, larger additions of these nutrients are needed than on other soils in the unit. A few areas need lime.

CAPABILITY UNIT IIIe-2

This unit consists of strongly sloping, well-drained or somewhat excessively drained soils on uplands. These soils have a friable, medium-textured surface layer, subsoil, and substratum.

These soils are moderately permeable and have a high available water capacity. The uneroded soils have a thicker surface layer than the eroded soils. In some severely eroded areas the subsoil is exposed. The organic-matter content is low to moderate. Reaction is slightly acid to mildly alkaline in the surface layer and slightly acid to moderately alkaline below the sur-

face layer. Available nitrogen is very low to low, available phosphorus is very low to low, and available potassium is very low. These soils are subject to runoff and erosion. Soil tilth is generally good, but it is somewhat poorer in the eroded areas.

These soils are used for cultivated crops and for pasture. Cultivated areas are used for corn, soybeans, oats, and meadow. These soils are subject to erosion, but are moderately suited to growing row crops if erosion is controlled.

The major management need is controlling erosion. Terraces and contour tillage are generally used. Terraces are difficult to establish in places because of the size and the shape of areas and the irregular slopes. Grassed waterways are used in places. Maintaining organic-matter content, soil tilth, and fertility is also important, especially in the eroded areas.

Crops respond well to fertilization. Because some of the soils are alkaline and very low in available nitrogen, phosphorus, and potassium, larger additions of these nutrients are needed. Some areas need lime.

CAPABILITY UNIT IIIe-3

This unit consists of gently sloping, somewhat excessively drained to excessively drained soils. These soils formed in glacial outwash or alluvium on uplands and stream benches.

These soils are moderately rapidly permeable or rapidly permeable in the upper part and very rapidly permeable or rapidly permeable in the substratum. They have mainly low or very low available water capacity. The organic-matter content is low. The available nitrogen, phosphorus, and potassium are very low to low. The soils are subject to runoff and erosion, and they are droughty.

These soils are used for cultivated crops and pasture. Cultivated areas are used for corn, soybeans, oats, and meadow crops. Row crops are moderately suited if erosion is controlled. Hay and pasture crops are better suited in most years, because the soils are also droughty. Grain sorghum is generally better suited than corn.

Control of erosion and soil blowing are needed. Blowing sand sometimes damages young plants. These soils are not generally terraced, but they can be tilled on the contour. Minimum tillage and crop residue on the surface help conserve moisture and reduce the hazard of soil blowing. In larger areas, alternate strips of hay crops and row crops reduce the risk of soil blowing when the soils are being prepared for planting. If row crops, particularly corn, are grown the final stand should be reduced because the supply of available moisture is inadequate. Maintaining the organic-matter content and soil tilth is important.

Crop response to fertilization is moderate or poor. Some areas need additions of lime.

CAPABILITY UNIT IIIe-4

This unit consists of moderately sloping and strongly sloping, somewhat excessively drained or excessively drained soils. These soils formed mainly in glacial till or outwash on the uplands. A few areas are on stream benches. The soil that formed in glacial till is in a complex with some of the other soils and is well drained.

These soils are moderately permeable to very rapidly permeable. The available water capacity ranges from very low to high. The organic-matter content is low or very low, but is moderate in one of the soils. Reaction typically ranges from mildly alkaline to slightly acid in the surface layer. Available nitrogen, phosphorus, and potassium are very low to low.

These soils are used for cultivated crops and pasture. Cultivated areas are used for corn, soybeans, oats, and meadow crops. Row crops are moderately suited if erosion is controlled. Meadow crops or pasture grasses are better suited in most years, because the soils are also droughty. Grain sorghum is generally better suited than corn.

Control of erosion and soil blowing is needed. Blowing sand sometimes damages young plants where the surface layer is sandy loam. These soils are generally not terraced, but they can be tilled on the contour. Minimum tillage and crop residue on the surface help conserve moisture and reduce the hazard of soil blowing. For optimum yields of row crops, particularly corn, the final stand should be reduced because the supply of available moisture is inadequate. Maintaining organic-matter content and soil tilth is important.

Crop response to fertilization is moderate or poor. The response, however, is ofter better on the loam soils. Lime is needed in some areas.

CAPABILITY UNIT IIIw-1

This unit consists of poorly drained and very poorly drained soils in shallow depressions on uplands, outwash plains, and stream benches. These soils have a silty clay loam or silt loam surface layer and a silty clay loam, clay loam, or silty clay subsoil. Areas on benches and in outwash areas have sand and gravel at a depth of about 4 feet. These soils are very wet. Water ponds in most areas in spring and during other periods of high rainfall. Crops are frequently drowned.

These soils are moderately permeable to slowly permeable. They have a high available water capacity. The organic-matter content is high. Reaction is generally mildly alkaline to slightly acid in the surface layer. The available phosphorus is very low, available potassium is very low to low, and available nitrogen is medium to low. These soils warm up slowly in spring. Tillage is often delayed.

Most areas are small and are farmed along with the surrounding soils. Corn and soybeans are the major crops, but an occasional crop of oats and meadow is grown. Legumes are subject to severe winterkill. Frequently they are drowned out. Row crops are moderately suited if drainage is adequate. Tile drainage works well in most areas, but not where the subsoil is silty clay. Open intakes on tile lines and surface drains, however, drain these areas well enough that they can be cropped in most years. Maintaining soil tilth is important.

Crops respond well to fertilization. Lime is needed on some of the soils.

CAPABILITY UNIT IIIw-2

This unit consists of very poorly drained soils on

uplands in shallow depressions that were formerly marshes, swamps, or shallow lakes. These soils have a mucky silt loam or muck surface layer and a silt loam, clay loam, or silty clay loam subsoil or substratum.

These soils are slowly permeable or moderately slowly permeable. The surface layer is friable and in good tilth. The soils are very wet, and most areas pond water in spring and during other periods of high rainfall. Crops frequently drown out. The available water capacity is high. The organic-matter content is very high. Reaction is generally neutral or mildly alkaline. The available nitrogen is medium to high, and available phosphorus and potassium are very low to low. These soils warm up slowly in spring.

Areas that are adequately drained are used for row crops. Areas that are partially drained are used for grasses that tolerate wetness, such as reed canarygrass. Undrained areas are suitable for wildlife. Row crops are moderately suited if drainage is adequate. Corn is the main crop. Because crops are susceptible to damage from frost early in fall, early maturing varieties are desirable. Small grain and soybeans tend to lodge. Control of grass and weeds is difficult. If suitable outlets are available, tile drains function well. Open ditches or intake drains leading to tile lines are needed to prevent ponding.

Crops respond well to fertilization, especially to applications of phosphorus and potassium. Because the soils are cold early in the season, the use of starter or row fertilizer containing nitrogen is generally beneficial. Generally no lime is needed.

CAPABILITY UNIT IIIw-3

Wabash silty clay, 0 to 2 percent slopes, the only soil in this unit, is a nearly level, very poorly drained soil on bottom land. It has a deep, firm silty clay surface layer and a firm silty clay subsoil that is very slowly permeable.

This soil has a high available water capacity and a high content of organic matter. Reaction is neutral to slightly acid. Available nitrogen is low to medium, available phosphorus is very low, and available potassium is very low to low. The soil is at low elevation and is usually flooded when streams overflow. It is slow to warm in spring. If worked when wet, it dries cloddy and hard and seedbeds are difficult to prepare. By midsummer, deep cracks have formed.

This soil is used for cultivated crops and permanent pasture. Corn and soybeans are the main crops. Row crops are moderately suited if drainage is adequate and overflow is not too serious. The soil is often plowed in fall so that freezing and thawing will improve tilth and make preparation of a good seedbed easier. The water table is high, and water collects from upland runoff and from floodwater. In places shallow ditches remove surface water. Tile drains function poorly in the clayey, very slowly permeable subsoil.

Crops respond well to fertilization. The fine-textured, very slowly permeable subsoil and inadequate drainage limit root development and the response to fertilization to some extent. Generally no lime is needed.

CAPABILITY UNIT IIIs-1

This unit consists of nearly level, somewhat poorly drained and somewhat excessively drained or excessively drained soils. These soils formed in glacial outwash or alluvium on uplands and stream benches.

These soils are moderately rapidly permeable or rapidly permeable or very rapidly permeable. They have a moderate, low, or very low available water capacity. The organic-matter content is low. Reaction is typically neutral to slightly acid in the surface layer. Available nitrogen, phosphorus, and potassium are very low to low. The soils are droughty and subject to soil blowing.

These soils are used for cultivated crops and for pasture. Cultivated areas are used for corn, soybeans, oats, and meadow crops. Grain sorghum is generally better suited than corn. Row crops are moderately suited. Hay and pasture crops are better suited in most years, because the soils are droughty.

Minimum tillage and crop residue on the surface help conserve moisture and reduce the hazard of soil blowing. Blowing sand sometimes damages young plants. In larger areas, planting alternate strips of hay crops and row crops protects the soil against blowing. If row crops, particularly corn, are grown, the final stand should be reduced because the supply of available water is inadequate. Maintaining organic-matter content and soil tilth is important.

Crops normally give only moderate or poor response to fertilization. Some areas need additions of lime.

CAPABILITY UNIT IVe-1

Storden loam, 14 to 18 percent slopes, the only soil in this unit, is a somewhat excessively drained soil in the uplands. It has a friable, medium-textured surface layer and substratum.

This soil is moderately permeable. It has a high available water capacity, but runoff is rapid. Consequently, the amount of water available is seldom at capacity. Some areas are severely eroded and the substratum is exposed. The organic-matter content is low, except in the severely eroded areas where it is very low. Reaction is mildly alkaline or moderately alkaline. Available nitrogen, phosphorus, and potassium are very low. The hazard of erosion is serious.

This soil is used for cultivated crops and for pasture. Cultivated areas are used mostly for corn, oats, and meadow, and occasionally soybeans. Row crops are moderately suited if erosion is controlled. Soybeans are not so well suited. They tend to leave the soil loose and mellow and in a condition more likely to erode.

The major management need is controlling erosion. Terraces and contour tillage are used. Level cut and fill terraces are generally better suited than standard terraces, because during construction the average degree of slope is reduced. In constructing standard terraces, the average degree of slope is increased. Terraces are difficult to establish in some places because of the size and the shape of the areas and the irregular slopes. Grassed waterways are used in places. Maintaining organic-matter content, soil tilth, and fertility is also important.

Crops respond well to fertilization. No lime is needed.

CAPABILITY UNIT IVe-2

This unit consists of Storden-Salida complex, 14 to 18 percent slopes. The soils are moderately steep and somewhat excessively drained or excessively drained. They formed in glacial till or outwash on uplands.

These soils are moderately permeable or very rapidly permeable and have a high or very low available water capacity. The organic-matter content is low or very low. Reaction is neutral to moderately alkaline in the surface layer. Available nitrogen, phosphorus, and potassium are very low. Water runs off these soils rapidly. The hazard of erosion is serious.

These soils are used for cultivated crops and pasture. Cultivated areas are used for corn, oats, and meadow crops. The soils are moderately suited to row crops, but are better suited to hay and pasture crops. Areas that are in permanent pasture can be improved by renovating, by using fertilizer, and by seeding more productive species.

Control of erosion and soil blowing is needed. No terraces are constructed where there is danger of exposing coarse-textured material. Contour tillage, minimum tillage, and crop residue on the surface help conserve moisture and reduce the hazard of soil blowing. Maintaining organic-matter content and soil tilth is important.

Crop response to fertilization is good to poor. No lime is needed.

CAPABILITY UNIT Vw-1

Spillville loam, channeled, 0 to 2 percent slopes, the only soil in this unit, is on bottom land. Wetness is a hazard. Most areas have a seasonal high water table. Some are frequently flooded and are cut by old meandering stream channels.

This soil is somewhat poorly drained. Some areas remain wet, because they are low and adjacent to streams and flood frequently. Most areas are loam, but some areas adjacent to the stream are sandy. Some places receive deposition from floods. In general, these soils are high in organic-matter content. Available water capacity is high, except in some sandy areas. Reaction is typically neutral, but in places of recent deposition it is mildly alkaline.

Most areas are in permanent pasture and have growths of trees and brush. A few are cultivated. Planning land use is difficult because of the uncertainty and frequency of flooding. The potential for cultivation is good if flooding is not too serious, or if stream channels can be straightened or levees constructed. In some areas the trees and brush can be removed, the channels filled, and artificial drainage provided. Some pastures can be improved by fertilizing and by planting more productive grasses and legumes. Some areas are suitable for trees and wildlife habitat. Improved stands and species, however, would provide better habitat.

CAPABILITY UNIT VIe-1

Storden loam, 18 to 25 percent slopes, the only soil in this unit, is a steep, somewhat excessively drained soil in uplands. It has a friable loam surface layer and substratum.

The soil is moderately permeable and has a high available water capacity. The organic-matter content is low. Reaction is mildly alkaline in the surface layer and moderately alkaline in the substratum. Available nitrogen, phosphorus, and potassium are very low. Water runs off rapidly. The hazard of erosion is serious.

This soil is used mostly for pasture, but a few areas that are adjacent to less sloping soils are used for row crops. The soil is poorly suited to row crops. It is better suited to small grain, hay, and pasture. Small, odd areas within fields of less sloping cropland are suitable for development for wildlife habitat. Areas that are in permanent pasture generally should be renovated, fertilized, and seeded to more productive species to increase productivity.

The major management needs are controlling erosion and maintaining fertility. Both can be accomplished with little difficulty if the soil is used for small grain, hay, or pasture. If the soil is used for row crops, controlling erosion is difficult. Overgrazing should be avoided because it increases the hazard of erosion.

Crops respond well to fertilization. Because the soil is alkaline and very low in available nutrients, larger additions of fertilizer are needed than on other soils. No lime is needed.

CAPABILITY UNIT VIIw-1

Only Marsh is in this unit. Marsh is covered with water most of the time. It is not suitable for farming, but does provide food and nesting places for waterfowl, muskrats, and upland game animals. Some areas can be improved as habitat by providing a more constant water level. Marsh can provide income and recreation through the trapping of muskrats and the sale of hunting and trapping privileges.

Predicted yields

Table 2 lists predicted average yields of the principal crops in the county under a high level of management. Under this level of management, seedbed preparation, planting, and tillage provide for adequate populations of adapted varieties; erosion is controlled; the organic-matter content and soil tilth are maintained; the level of fertility for each crop is maintained, as indicated by soil tests and field trials; the water level in wet soils is controlled; excellent weed and pest control are provided; and fieldwork is timely.

Many sources of yield information were used to make these estimates. They included data from the Federal census, from the Iowa farm census, from experimental farms and cooperative experiments with farmers, and from on-farm experience by soil scientists, extension workers, and others.

The yield predictions are meant to serve as guides. They are only approximate values and should be so considered. The comparative yields between soils will be of more value than actual yield figures to many users. Those relationships are likely to remain consistent over a period of years. In recent years, however, actual yields have been increasing. If the yields continue to increase as expected, predicted yields in

TABLE 2.—*Predicted average yields per acre of principal crops under high-level management*

[Absence of data indicates that the crop is not commonly grown on the soil or is not suited to the soil. Only arable soils are listed]

Soil	Corn	Soybeans	Oats	Alfalfa-brome hay	Alfalfa-brome pasture
	Bu	*Bu*	*Bu*	*Tons*	*AUD* [1]
Biscay clay loam, deep, 0 to 2 percent slopes	93	35	74	3.9	195
Blue Earth mucky silt loam, 0 to 1 percent slopes	69	24	51	2.7	135
Calco silty clay loam, 0 to 2 percent slopes	92	32	72	3.7	185
Canisteo silty clay loam, 0 to 2 percent slopes	98	33	80	3.9	195
Clarion loam, 2 to 5 percent slopes	102	39	83	4.2	210
Clarion loam, 5 to 9 percent slopes	98	37	79	4.1	205
Clarion loam, 5 to 9 percent slopes, moderately eroded	95	36	77	4.0	200
Clarion loam, 9 to 14 percent slopes, moderately eroded	87	32	70	3.6	180
Clarion-Estherville complex, 2 to 5 percent slopes	77	26	63	3.2	160
Clarion-Estherville complex, 5 to 9 percent slopes, moderately eroded	69	24	55	2.9	145
Clarion-Storden loams, 2 to 5 percent slopes	98	38	78	4.1	205
Colo silty clay loam, 0 to 2 percent slopes	97	38	73	3.9	195
Colo silty clay loam, 2 to 4 percent slopes	93	34	69	3.4	170
Colo-Spillville complex, 2 to 5 percent slopes	86	32	60	3.4	170
Crippin loam, 0 to 3 percent slopes	105	39	84	4.3	215
Cylinder loam, deep, 0 to 2 percent slopes	89	30	70	3.7	185
Dickman fine sandy loam, loamy substratum, 0 to 2 percent slopes	49	17	39	2.0	100
Dickman fine sandy loam, loamy substratum, 2 to 5 percent slopes	47	16	38	2.0	100
Estherville sandy loam, 0 to 2 percent slopes	41	13	29	1.7	85
Estherville sandy loam, 2 to 5 percent slopes	36	11	26	1.4	70
Estherville sandy loam, 5 to 9 percent slopes, moderately eroded	------	------	16	0.7	35
Estherville loam, 0 to 2 percent slopes	48	16	38	2.0	100
Estherville loam, 2 to 5 percent slopes	45	14	36	1.9	95
Farrar fine sandy loam, 5 to 9 percent slopes	67	24	52	2.7	135
Flagler sandy loam, calcareous subsoil variant, 0 to 2 percent slopes	47	15	37	2.0	100
Flagler sandy loam, calcareous subsoil variant, 2 to 5 percent slopes	42	13	30	1.7	85
Hanska loam, moderately deep, 0 to 2 percent slopes	74	27	57	3.1	155
Harps loam, 0 to 2 percent slopes	88	28	71	3.7	185
Linder loam, 0 to 2 percent slopes	54	19	42	2.2	110
Mayer loam, moderately deep, 0 to 2 percent slopes	81	25	63	3.2	160
Mayer loam, sandy loam subsoil, 0 to 2 percent slopes	69	21	50	2.6	130
Nicollet loam, 1 to 3 percent slopes	110	42	88	4.6	230
Okoboji silty clay loam, 0 to 1 percent slopes	78	29	62	3.1	155
Okoboji mucky silt loam, 0 to 1 percent slopes	97	33	72	3.2	160
Okoboji silty clay loam, benches, 0 to 1 percent slopes	78	28	60	3.0	150
Palms muck, 0 to 1 percent slopes	75	28	60	2.9	145
Rolfe silt loam, 0 to 1 percent slopes	70	25	54	2.8	140
Salida gravelly sandy loam, 4 to 12 percent slopes	13	5	10	0.5	25
Spillville loam, 0 to 2 percent slopes	108	41	86	4.2	210
Spillville loam, 2 to 5 percent slopes	104	39	84	4.4	220
Spillville loam, channeled, 0 to 2 percent slopes	------	------	------	------	165
Storden loam, 5 to 9 percent slopes	86	32	69	3.6	180
Storden loam, 9 to 14 percent slopes	77	29	62	3.2	160
Storden loam, 14 to 18 percent slopes	63	23	50	2.6	130
Storden loam, 18 to 25 percent slopes	------	------	------	2.0	100
Storden-Salida complex, 5 to 9 percent slopes	56	21	45	2.3	115
Storden-Salida complex, 9 to 14 percent slopes	50	19	40	2.1	105
Storden-Salida complex, 14 to 18 percent slopes	31	11	25	1.3	65
Talcot clay loam, deep, 0 to 2 percent slopes	88	31	70	3.4	170
Truman silt loam, 0 to 2 percent slopes	106	40	85	4.5	225
Truman silt loam, 2 to 6 percent slopes	102	39	82	4.3	215
Wabash silty clay, 0 to 2 percent slopes	63	25	37	2.0	100
Wacousta silty clay loam, 0 to 1 percent slopes	93	35	74	3.7	185
Wadena loam, deep, 0 to 3 percent slopes	86	32	69	3.6	180
Waldorf silty clay loam, 0 to 2 percent slopes	95	36	76	3.9	195
Watseka loamy fine sand, 0 to 2 percent slopes	32	11	22	1.2	60
Webster silty clay loam, 0 to 2 percent slopes	102	38	82	4.0	200

[1] Animal-unit-days. The number of days that 1 acre will provide grazing for one animal unit, or 1,000 pounds of live weight, without damage to the pasture.

this table will soon be too low. Under the best techniques and management and ideal weather conditions, yields can exceed those predicted in table 2 by 30 to 40 percent.

Environmental Plantings

The soils of Palo Alto County are grouped according to their suitability for trees and shrubs.

Suitability plantings are listed in table 3 for shade, street borders, hedges and screens, woodland, windbreaks, and wildlife. Most trees planted in the county are planted for windbreaks (fig. 22). The lists are not intended to be complete, and the plants are not listed in order of suitability.

Wildlife Habitat [2]

An adequate plant cover, determined mainly by soil characteristics, is a basic requirement of all wildlife populations. Research has shown a direct relationship between soil fertility and numbers of wildlife. Characteristics of the soil such as slope, permeability, and drainage also affect the kind and number of wildlife in any given area.

Many factors affect development of wildlife habitat and the resulting populations. In intensively farmed areas, such as Palo Alto County, personal preferences mainly determine the types of crops planted and other uses of the land. The resulting type of vegetation, or lack of it, determines the kind of wildlife that can survive in the area.

Wildlife generally require three things from the habitat for survival: food, cover for protection from enemies and weather, and a suitable site to produce young. Fortunately, most farm crops provide food, cover, or a place to produce young for some type of wildlife. Sometimes proper habitat is not enough. Other factors, such as disease, extreme weather conditions, predacity, and hunting pressure affect wildlife populations. Therefore, good wildlife habitat is not a guarantee of abundant wildlife populations.

In table 4 the soils of Palo Alto County are rated for their potential to produce various habitat elements. These elements are then evaluated to determine their potential for supporting openland wildlife, woodland

[2] BILL D. WELKER, biologist, Soil Conservation Service, helped prepare this section.

Figure 22.—**Part of a good multipurpose windbreak. In the foreground are two rows of honeysuckle. In the background are several rows of deciduous trees.**

TABLE 3.—*Environmental*

Group number, description, and soil series	Additional properties	Shade trees	Street trees
Group 1. Somewhat poorly drained to well drained soils that are noncalcareous in the upper 18 inches. Available water capacity is moderate to high. Texture of the surface layer ranges from moderately coarse to moderately fine. Clarion, Cylinder, Farrar, Nicollet, Spillville, Truman, Wadena.	These fertile soils have properties generally favorable to good plant growth. Erosion is a hazard on sloping soils. Available water capacity is sometimes less than optimum during dry periods, especially on sloping to strongly sloping soils and on south- and southwest-facing slopes. Reaction of the surface layer is dominantly neutral or slightly acid.	American basswood, honeylocust, green ash, hackberry, sugar maple, silver maple.	Green ash, hackberry, pin oak, sugar maple.
Group 2. Poorly drained to very poorly drained soils. Available water capacity is moderate to very high. Texture of the surface layer ranges from moderately coarse to fine. Organic soils are included in this group. Biscay, Blue Earth, Calco, Canisteo, Colo, Colo-Spillville complex, Hanska,[1] Harps, Marsh, Okoboji, Palms, Rolfe, Talcot, Wabash, Wacousta, Waldorf, Webster.	These are wet soils, and some are subject to ponding or to flooding. Maximum duration of standing water is a few days to about a week, except during unusually wet periods. On Marsh, however, water generally stands throughout the growing season. Artificial drainage has been installed in many places to speed removal of excess water. Tilth is poor at times, especially on soils that have a fine-textured surface layer. Reaction in the surface layer is dominantly slightly acid to moderately alkaline.	Silver maple, hackberry, sycamore, green ash.	Hackberry, sycamore, green ash.
Group 3. Moderately well drained to somewhat excessively drained soils that are calcareous within a depth of 10 inches. Available water capacity is moderate to high. Texture of the surface layer is medium. Clarion-Storden, Crippin,[3] Mayer,[4] Storden.	These soils have properties generally favorable to good plant growth, but they have excess lime at or near the surface. This inhibits growth of many kinds of trees and shrubs. The bottom land soils are subject to flooding, which is normally short in duration. Available water capacity is often less than optimum on the sloping soils, especially on south- and southwest-facing slopes. The hazard of erosion is serious on the sloping soils. Cultivation is limited on the steep and very steep soils. Reaction in the surface layer is generally mildly alkaline or moderately alkaline.	Green ash, hackberry, silver maple.	Green ash, hackberry ----
Group 4. Well drained to excessively drained soils. Available water capacity is very low and low. Texture of the surface layer is coarse to medium. Clarion-Estherville complex, Dickman,[5] Estherville, Flagler,[5] Linder,[3] Salida, Storden-Salida complex, Watseka.[3]	Plant growth is limited by the lack of adequate available water during dry periods. On sloping soils soil blowing and water erosion are hazards. Reaction of the surface layer is dominantly neutral to slightly acid.	Scarlet oak, bur oak, hackberry, green ash, silver maple.	Hackberry, green ash ----

[1] Sand and gravel at a depth of 24 to 32 inches, low available water capacity.
[2] Not well suited on very poorly drained soils.
[3] Somewhat poorly drained.

planting groups

Hedges, screens	Woodland planting	Windbreak planting	Wildlife planting
Lilac, American cranberrybush, Tatarian honeysuckle, silky dogwood, arrowwood viburnum, hawthorn.	Eastern white pine, red pine, Norway spruce, Scotch pine, white spruce, European larch, black walnut, sugar maple, poplar.	Eastern white pine, red pine, Colorado blue spruce, Norway spruce, Scotch pine, white spruce, European larch, eastern redcedar, green ash, hackberry, eastern cottonwood, Douglas-fir, Tatarian honeysuckle, pin oak, Russian-olive, silver maple, lilac.	Blackhaw, lilac, gray dogwood, alternate-leaf dogwood, autumn-olive, Tatarian honeysuckle, Midwest Manchurian crabapple.
Northern white-cedar, silky dogwood, American cranberrybush, Lombardy poplar.	Eastern cottonwood	Silver maple, poplar, laurel willow, sycamore, green ash, hackberry,[2] northern white-cedar, eastern redcedar,[2] white spruce,[2] Norway spruce.[2]	Redosier dogwood, eastern redcedar, northern white-cedar, silky dogwood, American cranberrybush.
Eastern redcedar, honeysuckle, Russian-olive, Siberian peashrub.	Ponderosa pine, Austrian pine, Scotch pine, hackberry, poplar, green ash.	Ponderosa pine, Austrian pine, green ash, hackberry, Russian-olive, eastern redcedar, northern white-cedar.	American plum, Amur honeysuckle, Tatarian honeysuckle, Russian-olive, eastern redcedar.
Eastern redcedar, Russian-olive, honeysuckle, lilac, Siberian peashrub.	Eastern white pine, Scotch pine, European larch, eastern redcedar.	Red pine, eastern white pine, Scotch pine, eastern redcedar, green ash, hackberry, Siberian peashrub.	Blackhaw, lilac, gray dogwood, alternate-leaf dogwood, autumn-olive.

[4] Poorly drained.
[5] Moderate available water capacity.

TABLE 4.—*Soil interpretations for wildlife habitat*

Soil series and map symbols	Potential for—							Potential for development of habitat for wildlife—		
	Grain and seed crops	Grasses and legumes	Wild herbaceous plants	Hardwood trees and shrubs	Coniferous plants and shrubs	Wetland plants	Shallow water areas	Openland	Woodland	Wetland
Biscay: 259	Good to fair [1]	Good to fair [1]	Fair	Fair	Fair	Good	Fair	Good to fair [1]	Fair	Fair.
Blue Earth: 511	Poor to very poor.[1]	Poor to very poor.[1]	Poor	Poor	Poor	Good	Good	Poor to very poor.[1]	Poor	Good.
Calco: 733	Good to fair [1]	Good to fair [1]	Fair	Fair	Fair	Good	Good	Good to fair [1]	Fair	Good.
Canisteo: 507	Good to fair [1]	Good to fair [1]	Fair	Fair	Fair	Good	Good	Good to fair [1]	Fair	Good.
Clarion:										
138B	Good	Good	Good	Good	Good	Poor	Very poor	Good	Good	Very poor.
138C	Good	Good	Good	Good	Good	Poor	Very poor	Good	Good	Very poor.
138C2	Good	Good	Good	Good	Good	Poor	Very poor	Good	Good	Very poor.
138D2	Fair	Good	Good	Good	Good	Very poor	Very poor	Good	Good	Very poor.
181B	Fair	Fair	Fair	Fair	Fair	Very poor	Very poor	Fair	Fair	Very poor.
181C2	Poor	Poor	Fair	Poor	Poor	Very poor	Very poor	Poor	Poor	Very poor.
638B	Good	Good	Good	Good	Good	Poor	Very poor	Good	Good	Very poor.
Colo:										
133	Good to fair [1]	Good to fair [1]	Fair	Fair	Fair	Good	Good	Good to fair [1]	Fair	Good.
133B	Good	Good	Fair	Fair	Fair	Fair	Fair	Good	Fair	Fair.
585B	Good to fair [1]	Good to fair [1]	Fair	Fair	Fair	Poor	Poor	Good to fair [1]	Fair	Poor.
Crippin: 655	Good	Good	Good	Good	Good	Fair	Fair	Good	Good	Fair.
Cylinder: 203	Fair	Good	Good	Good	Good	Fair	Very poor	Good	Good	Poor.
Dickman:										
324	Fair	Fair	Fair	Fair	Fair	Very poor	Very poor	Fair	Fair	Very poor.
324B	Fair	Fair	Fair	Fair	Fair	Very poor	Very poor	Fair	Fair	Very poor.
Estherville:										
34	Poor	Poor	Fair	Poor	Poor	Very poor	Very poor	Poor	Poor	Very poor.
34B	Poor	Poor	Fair	Poor	Poor	Very poor	Very poor	Poor	Poor	Very poor.
34C2	Poor	Poor	Fair	Poor	Poor	Very poor	Very poor	Poor	Poor	Very poor.
72	Fair	Fair	Fair	Fair	Fair	Very poor	Very poor	Fair	Fair	Very poor.
72B	Fair	Fair	Fair	Fair	Fair	Very poor	Very poor	Fair	Fair	Very poor.
Farrar: 253C2	Fair	Fair	Fair	Fair	Fair	Very poor	Very poor	Fair	Fair	Very poor.
Flagler:										
823	Fair	Fair	Fair	Fair	Fair	Very poor	Very poor	Fair	Fair	Very poor.
823B	Fair	Fair	Fair	Fair	Fair	Very poor	Very poor	Fair	Fair	Very poor.
Hanska: 150	Fair	Fair	Fair	Fair	Fair	Fair	Poor	Fair	Fair	Poor.
Harps: 95	Fair to poor [1]	Fair to poor [1]	Fair	Poor	Very Poor	Good	Fair	Fair to poor [1]	Fair	Fair.
Linder: 224	Fair	Good	Good	Fair	Fair	Poor	Very Poor	Good	Fair	Very poor.
Marsh: 354	Very poor	Very poor	Very poor.	Very Poor	Very Poor	Good	Good	Very poor	Very Poor	Good.
Mayer:										
658	Good to fair [1]	Good to fair [1]	Fair	Fair	Fair	Good	Poor	Good to fair [1]	Fair	Fair.
895	Good to fair [1]	Good to fair [1]	Fair	Fair	Fair	Good	Poor	Good to fair [1]	Fair	Fair.

TABLE 4.—*Soil interpretations for wildlife habitat*—Continued

Soil series and map symbols	Potential for—							Potential for development of habitat for wildlife—		
	Grain and seed crops	Grasses and legumes	Wild herbaceous plants	Hardwood trees and shrubs	Coniferous plants and shrubs	Wetland plants	Shallow water areas	Openland	Woodland	Wetland
Nicollet: 55	Good	Good	Good	Good	Good	Fair	Fair	Good	Good	Fair.
Okoboji:										
6	Fair to very poor.[1]	Fair to very poor.[1]	Fair	Poor	Poor	Good	Good	Fair to very poor.[1]	Poor	Good.
90	Fair to very poor.[1]	Fair to very poor.[1]	Fair	Poor	Poor	Good	Good	Fair to very poor.[1]	Poor	Good.
T6	Fair to very poor.[1]	Fair to very poor.[1]	Fair	Poor	Poor	Good	Good	Fair to very poor.[1]	Poor	Good.
Palms: 221	Poor to very poor.[1]	Poor to very poor.[1]	Poor	Poor	Poor	Good	Good	Poor to very poor.[1]	Poor	Good.
Rolfe: 274	Poor to very poor.[1]	Poor to very poor.[1]	Poor	Poor	Poor	Good	Good	Poor to very poor.[1]	Poor	Good.
Salida: 73C	Very poor	Poor	Poor	Very poor	Very poor	Very poor	Very poor	Poor	Very poor	Very poor.
Spillville:										
485	Good	Good	Good	Good	Good	Poor	Poor	Good	Good	Poor.
485B	Good	Good	Good	Good	Good	Poor	Poor	Good	Good	Poor.
C485	Very poor	Poor	Fair	Good	Good	Good	Good	Poor	Fair	Good.
Storden:										
62C	Fair	Fair	Fair	Fair	Fair	Very poor	Very poor	Fair	Fair	Very poor.
62D	Fair	Fair	Fair	Fair	Fair	Very poor	Very poor	Fair	Fair	Very poor.
62E	Poor	Fair	Fair	Fair	Fair	Very poor	Very poor	Fair	Fair	Very poor.
62F	Very poor	Poor	Fair	Fair	Fair	Very poor	Very poor	Poor	Fair	Very poor.
639C	Poor	Poor	Fair	Poor	Poor	Very poor	Very poor	Poor	Poor	Very poor.
639D	Poor	Poor	Fair	Poor	Poor	Very poor	Very poor	Poor	Poor	Very poor.
639E	Poor	Poor	Fair	Poor	Poor	Very poor	Very poor	Poor	Poor	Very poor.
Talcot: 559	Good to fair [1]	Good to fair [1]	Fair	Fair	Fair	Good	Fair	Good to fair [1]	Fair	Fair.
Truman:										
339	Good	Good	Good	Good	Good	Poor	Very poor	Good	Good	Very poor.
339B	Good	Good	Good	Good	Good	Poor	Very poor	Good	Good	Very poor.
Wabash: 172	Poor	Fair	Poor	Poor	Poor	Fair	Good	Poor	Poor	Fair.
Wacousta: 506	Fair to very poor.[1]	Fair to very poor.[1]	Fair	Poor	Poor	Good	Good	Fair to very poor.[1]	Poor	Good.
Wadena: 308	Good	Good	Good	Good	Good	Poor	Very poor	Good	Good	Very poor.
Waldorf: 390	Good to fair [1]	Good to fair [1]	Fair	Fair	Fair	Good	Good	Good to fair [1]	Fair	Good.
Watseka: 141	Poor	Poor	Fair	Poor	Poor	Very Poor	Very Poor	Poor	Poor	Very poor.
Webster: 107	Good to fair [1]	Good to fair [1]	Fair	Fair	Fair	Good	Good	Good to fair [1]	Fair	Good.

[1] Poorly drained and very poorly drained soils that commonly are artificially drained are given dual ratings. The ratings are for drained and undrained soils, respectively.

wildlife, and wetland wildlife. Ratings are on the basis of good, fair, poor, or very poor.

Soils having the best potential for producing openland wildlife habitat are those that can produce good crops of grain and seed, grasses and legumes, and wild herbaceous plants. The soils having the best potential for producing woodland wildlife habitat are those on which good stands of hardwood or coniferous trees and shrubs can be grown. The soils having the best potential for producing wetland wildlife are those that can be developed into shallow water areas and those on which wetland plants can be grown.

Poorly drained and very poorly drained soils can produce different vegetation if they are artificially drained. In table 4 such soils are rated for both drained and undrained conditions.

Wildlife resources in Palo Alto County have important recreational and esthetic values. The ringneck pheasant, various waterfowl, and the white-tailed deer are the main game in the county, although there are many other species of mammals and birds. Fishing is generally good in the lakes and streams.

In the past waterfowl habitat in the county was excellent. Intensive farming and the draining of many small sloughs have reduced this habitat, but many migratory ducks and geese continue to rest and feed each fall in the remaining wetlands (fig. 23).

Most of the white-tailed deer are in wooded areas adjacent to the rivers and creeks. Some deer are also attracted to the wooded areas surrounding many of the lakes and to larger marshes in Palo Alto County.

Whitetail jackrabbit, cottontail rabbit, red fox, mink, beaver, muskrat, and Hungarian partridge find food and cover in various parts of the county. Among the common songbirds are robins, English sparrows, meadowlarks, blackbirds, mourning doves, purple martins, wrens, bluebirds, chickadees, brown thrashers, swallows, orioles, woodpeckers, and starlings.

The introduced ringneck pheasant has adapted itself well to this county. The number varies from year to year, depending on the amount of nesting cover. Lack of cover in winter and at nesting time and severe weather at nesting time greatly reduce the number of pheasant.

The best pheasant range is on associations 4 and 5, which are shown on the general soil map and described under the heading "General Soil Map." These associations contain wet and marshy areas that provide the needed winter cover, as well as nesting areas along the edges of fields.

Pheasants are somewhat less abundant on the remaining soil associations. Many of the soils are nearly level or gently sloping, and much of the acreage is

Figure 23.—**Marsh provides good natural habitat for waterfowl and muskrats.**

farmed intensively. Consequently, little food and cover is available for pheasant in winter or for nesting.

Nesting cover is the most critical factor affecting the number of pheasant. The most successful nestings in intensively farmed areas are in road ditches and along fence lines, but these are few and produce only a limited number of pheasant. Studies by the Iowa Conservation Commission have shown that pheasant populations can be significantly increased if the plant cover in ditches and along fence lines is left unclipped until early in summer.

Winter cover can be provided through farmstead windbreaks and wildlife plantings. Winter cover should be near a source of food. A few rows of grain left in a field adjacent to a windbreak or other wildlife planting would be excellent.

Small, odd-shaped areas, unsuitable for farming, can provide excellent wildlife habitat. The strongly sloping to steep Salida, Storden, and Estherville soils, as well as marshes and depressional soils in associations 5 and 6, are most likely to have these odd areas. The other associations may contain small steep, eroded, or gravelly areas of crops; gravel pits; railroad rights-of-way; or tracts of land cut off from the rest of a field by a stream or drainage ditch that are also well suited to wildlife habitat.

The type of existing cover and location of the odd areas determine if any additional seeding or planting is needed. Development of many of these small areas for wildlife habitat requires only protection from fire and grazing. For others, planting and maintenance may be necessary. A satisfactory wildlife habitat consists of low-growing cover, such as locally adapted grasses and legumes, to provide nesting sites and some food; a taller cover of grasses and shrubs to supply refuge and loafing areas; and clumps of evergreen trees and shrubs to provide the best winter cover.

Maintenance of the wildlife areas is most important. Areas should not be mowed before midsummer in order to protect the ground-nesting birds and rabbits. To maintain an adequate ground cover of grasses and legumes, it may be necessary to control invading woody plants by chemical or mechanical means. Reseeding is needed occasionally. Landowners who wish to plant and maintain wildlife areas that will provide good nesting, adequate food, and weather protection may obtain assistance in planning from the Soil Conservation Service or the wildlife management biologist of the Iowa Conservation Commission.

The two major natural lakes, Five Island and Lost Island, provide excellent fishing. Yellow perch, bullhead, bass, and bluegill are the most numerous. There are a few walleye and northern pike. Carp are abundant and cause damage in spawning areas and to young fish. Five Island Lake and some of the other lakes in the county are subject to winterkill. Winterkill is a result of an insufficient supply of oxygen caused by the shallowness and the high organic-matter content of the lake bottom while the lake is covered with ice. Fishing is fair in the West Fork of the Des Moines River. The most numerous fish are bullhead and carp, but channel catfish, walleye pike, and northern pike are common.

Engineering [3]

Some soil properties are of special interest to engineers because they affect the construction and maintenance of roads, airports, pipelines, facilities for storing water, erosion control structures, irrigation systems, drainage systems, building foundations, sewage disposal systems, and sanitary landfills. Among the properties most important are permeability to water, shear strength, compaction characteristics, soil drainage, shrink-swell potential, grain size, plasticity, and reaction. Depth to the water table, depth to bedrock, and topography are also important.

The information in this survey can be used to—

1. Make soil and land use studies that will aid in selecting and developing industrial, business, residential, and recreational sites.
2. Make preliminary estimates of the engineering properties of soils that will help in the planning of agricultural drainage systems, farm ponds, irrigation systems, terraces, waterways, and diversion terraces.
3. Make preliminary evaluations of soil and ground conditions that will aid in selecting highway and airport locations and in planning detailed investigations at the selected locations.
4. Locate probable sources of gravel, sand, or other construction materials.
5. Correlate performance of engineering structures with soil mapping units to develop information for planning that will be useful in designing and maintaining specified engineering practices and structures.
6. Determine the suitability of soil mapping units for cross-country movement of vehicles and construction equipment.
7. Supplement information obtained from other published maps and reports and aerial photographs to make maps and reports that can be used readily by engineers.
8. Develop other preliminary estimates for construction purposes pertinent to the particular area.

The engineering interpretations reported here can be useful for many purposes. It should be emphasized, however, that they do not eliminate the need for sampling and testing at the site of specific engineering works that involve heavy loads or where the excavations are deeper than the depth of the layers reported. Even in these situations, however, the soil map is useful for planning more detailed field investigations and for suggesting the kinds of problems that may be expected.

Information regarding the behavior and properties of the soils in Palo Alto County can be obtained from the detailed soil map at the back of the survey and from tables 5, 6, and 7 in this section. The information in the tables was obtained and evaluated from field experience; field performance; and the results of tests,

[3] VOLNEY H. SMITH, assistant State conservation engineer, SCS, helped prepare this section.

TABLE 5.—*Estimated soil properties*

[An asterisk in the first column indicates that at least one mapping unit in the series is made up of two or more kinds of soil. other series in the first column of this table. The symbol

Soil series and map symbols	Depth to seasonal high water table	Depth from surface	USDA texture	Classification	
				Unified	AASHTO
	Feet	*Inches*			
Biscay: 259 [1]	1–3	0–24	Clay loam	MH, ML, or CL	A–7
		24–36	Clay loam	CL	A–6 or A–7
		36–72	Sand and gravel	SW–SM or SM	A–1–b or A–2–4
Blue Earth: 511	0–1	0–14	Mucky silt loam	OL or OH	A–7
		14–60	Silty clay loam	OH, CH, or ML	A–7
Calco: 733 [1]	1–3	0–43	Silty clay loam	ML, MH, or CL	A–7
		43–57	Silty clay loam, clay loam.	CL or CH	A–7
		57–66	Loamy sand	SM or SC	A–2–4
Canisteo: 507	1–3	0–16	Silty clay loam	MH, CH, ML, or CL	A–7
		16–35	Clay loam	CL	A–6 or A–7
		35–60	Clay loam, sandy clay loam.	CL	A–6 or A–7
*Clarion: 138B, 138C, 138C2, 138D2, 181B, 181C2, 638B. For Estherville parts of 181B and 181C2, see Estherville 34, 34B, 34C2. For Storden part of 638B, see Storden series.	>5	0–14	Loam	CL–ML or CL	A–4 or A–6
		14–27	Clay loam	CL–ML or CL	A–4 or A–6
		27–60	Loam	CL–ML or CL	A–4 or A–6
*Colo: 133, 133B, 585B [1] For Spillville part of 585B, see Spillville series.	1–3	0–22	Silty clay loam	CL, CH, MH or ML	A–7
		22–50	Silty clay loam, clay loam.	CL or CH	A–7
		50–66	Clay loam	CH or MH	A–7
Crippin: 655	2–4	0–16	Loam	CL	A–6
		16–35	Loam	CL	A–6
		35–60	Loam	CL	A–6
Cylinder: 203	2–4	0–15	Loam	CL	A–6
		15–26	Loam	CL	A–6
		26–37	Loam to sandy loam.	SC, CL–ML, or SM–SC	A–4 or A–6
		37–60	Sand and gravel	SC or SM	A–1–b or A–2–4
Dickman: 324, 324B	>5	0–15	Fine sandy loam	SM–SC or SC	A–4
		15–22	Loamy fine sand	SM, SC or SM–SC	A–2–4
		22–46	Loamy fine and medium sand.	SM, SC or SM–SC	A–2–4
		46–52	Silty clay loam	CL or CH	A–7
		52–63	Silt loam	CL	A–6
Estherville:					
34, 34B, 34C2	>5	0–14	Sandy loam	SM, SC or SM–SC	A–2–4 or A–4
		14–17	Gravelly sandy loam.	SM–SC, SC, or SM	A–1–b or A–2–4
		17–60	Sand and gravel	SP–SM or SM	A–1–b
72, 72B	>5	0–11	Loam	CL–ML or CL	A–4 or A–6
		11–24	Sandy loam	SM, SC, or SM–SC	A–2–4 or A–4
		24–30	Gravelly sandy loam.	SM–SC, SC, or SM	A–1–b or A–2–4
		30–60	Sand and gravel	SP–SM or SM	A–1–b
Farrar: 253C	>5	0–14	Fine sandy loam	SM–SC or SC	A–4 or A–2–4
		14–32	Sandy loam and fine sandy loam.	SM–SC or SC	A–4 or A–2–4
		32–60	Loam	CL or CL–ML	A–4 or A–6

significant in engineering

Because these soils have different properties and limitations, it is necessary to follow carefully the instructions for referring to > means greater than; the symbol < means less than]

Percentage less than 3 inches passing sieve— No. 4 (4.7 mm)	No. 10 (2.0 mm)	No. 40 (0.42 mm)	No. 200 (0.074 mm)	Liquid limit	Plasticity index	Permea-bility	Available water capacity	Reaction	Shrink-swell potential
				Percent		*Inches per hour*	*Inches per inch of soil*	*pH*	
100	95–100	85–95	70–85	41–55	15–25	0.6–2.0	0.17–0.19	6.6–7.3	Moderate to high.
100	95–100	75–95	50–75	35–50	15–25	0.6–2.0	0.15–0.19	6.6–7.3	Moderate.
75–95	60–80	25–60	0–25	[2]NP–20	NP–5	6.0–>20	0.02–0.04	7.4–8.4	Very low to none.
------	------	100	95–100	41–55	15–25	0.6–2.0	0.22–0.24	7.9–8.4	Moderate.
------	100	95–100	85–95	41–55	11–25	0.2–0.6	0.18–0.20	7.9–8.4	High.
------	100	95–100	80–90	41–65	20–30	0.2–0.6	0.21–0.23	7.9–8.4	High.
------	100	90–100	75–90	41–60	20–30	0.2–0.6	0.18–0.20	7.9–8.4	High.
95–100	90–95	50–75	5–15	15–30	2–10	6.0–20.0	0.08–0.10	7.9–8.4	Low.
100	95–100	80–90	70–90	41–60	20–35	0.6–2.0	0.21–0.23	7.4–8.4	High.
95–100	95–100	80–90	60–80	30–50	15–30	0.6–2.0	0.15–0.19	7.9–8.4	Moderate to high.
95–100	95–100	75–80	50–75	30–50	15–30	0.6–2.0	0.14–0.16	7.9–8.4	Moderate.
95–100	95–100	80–90	50–75	25–40	5–15	0.6–2.0	0.20–0.22	6.1–7.3	Moderate.
95–100	90–100	80–90	50–75	25–40	5–15	0.6–2.0	0.15–0.19	6.6–7.3	Moderate.
90–100	85–100	75–80	50–75	25–40	5–15	0.6–2.0	0.17–0.19	7.9–8.4	Moderate.
------	100	95–100	95–100	41–65	20–40	0.2–0.6	0.21–0.23	6.1–7.3	High.
------	100	95–100	95–100	41–60	20–40	0.2–0.6	0.18–0.20	6.6–7.3	High.
------	100	95–100	95–100	50–70	20–40	<0.06	0.11–0.13	6.6–7.3	High.
95–100	95–100	80–90	60–80	30–40	11–25	0.6–2.0	0.20–0.22	7.4–8.4	Moderate.
95–100	90–100	80–90	60–80	30–40	11–20	0.6–2.0	0.17–0.19	7.4–8.4	Moderate.
90–100	85–100	75–90	55–80	30–40	11–20	0.6–2.0	0.17–0.19	7.9–8.4	Moderate.
98–100	90–100	80–90	50–80	30–40	11–25	0.6–2.0	0.20–0.22	6.6–7.3	Moderate.
95–100	85–100	75–90	50–75	30–40	11–20	0.6–2.0	0.17–0.19	6.6–7.3	Moderate.
95–100	75–95	60–75	40–60	25–35	5–15	0.6–2.0	0.17–0.19 to 0.12–0.14	6.6–7.3	Low.
75–95	60–80	25–60	5–25	5–25	NP	6.0–20.0	0.02–0.04	7.9–8.4	Low.
------	100	85–90	35–50	15–30	5–10	2.0–6.0	0.13–0.15	6.1–6.5	Low.
------	100	75–90	5–20	10–30	5–10	6.0–20.0	0.09–0.11	6.6–7.3	Very low to none.
------	100	60–80	5–20	10–30	5–10	6.0–20.0	0.09–0.11	6.6–7.3	Very low to none.
------	100	95–100	95–100	41–60	15–30	0.2–0.6	0.18–0.20	6.6–7.3	High.
------	100	95–100	95–100	30–40	11–20	0.6–2.0	0.20–0.22	6.6–7.3	Moderate.
90–100	70–80	50–70	30–50	25–35	5–10	2.0–6.0	0.13–0.15	6.6–7.3	Low.
70–90	60–70	20–40	5–20	20–30	2–10	2.0–6.0	0.11–0.13	6.6–7.3	Very low to none.
70–90	50–70	20–30	5–20	NP–15	NP–5	6.0–20.0	0.02–0.04	7.9–8.4	Very low to none.
95–100	90–100	50–80	50–65	25–40	5–15	0.6–2.0	0.20–0.22	6.6–7.3	Low.
90–100	70–80	50–70	30–50	25–35	5–10	2.0–6.0	0.12–0.14	6.1–6.5	Low.
70–90	60–70	20–40	5–20	20–30	2–10	2.0–6.0	0.11–0.13	6.6–7.3	Very low to none.
70–90	50–70	20–30	5–20	NP–15	NP–5	6.0–20.0	0.02–0.04	7.9–8.4	Very low to none.
------	100	30–60	30–45	15–30	5–10	2.0–6.0	0.13–0.15	6.1–6.5	Low.
------	100	30–60	30–45	15–30	5–10	2.0–6.0	0.12–0.14	6.6–7.3	Low.
90–100	85–100	75–85	50–75	25–40	5–15	0.6–2.0	0.17–0.19	6.6–7.8	Moderate.

TABLE 5.—*Estimated soil properties*

Soil series and map symbols	Depth to seasonal high water table	Depth from surface	USDA texture	Classification	
				Unified	AASHTO
	Feet	*Inches*			
Flagler: 823, 823B	>5	0–13	Fine sandy loam	SM–SC or SC	A–4 or A–2–4
		13–36	Fine sandy loam	SM–SC or SC	A–4 or A–2–4
		36–39	Gravelly sandy loam.	SM–SC or SC	A–4 or A–2–4
		39–60	Sand and gravel	SP–SM, SM or SP	A–1–b
Hanska: 150	1–3	0–13	Loam	CL or CL–ML	A–4
		13–25	Sandy loam	SM–SC or SC	A–4 or A–2–4
		25–60	Sand and gravel	SW–SM, SM, or SW	A–1–b
Harps: 95	1–3	0–15	Loam	CL	A–6 or A–7
		15–36	Clay loam	CL	A–6 or A–7
		36–60	Clay loam	CL	A–6 or A–7
Linder: 224	1–3	0–13	Loam	CL	A–6
		13–24	Sandy loam	SC or SM–SC	A–4, A–6 or A–2–4
		24–60	Sand and gravel	SP–SM or SM	A–2–4 or A–1–b
Marsh: 354	0		Peat	Pt	Muck.
No valid estimates can be made.					
Mayer:					
658 [1]	1–3	0–16	Loam	CL	A–6 or A–7
		16–30	Loam	CL	A–6 or A–7
		30–60	Sand and gravel	SP–SM or SM	A–1–b or A–2–4
895 [1]	1–3	0–20	Loam	CL	A–6
		20–32	Sandy loam	SM–SC or SC	A–4 or A–2–6
		32–63	Sand and gravel	SW–SM or SM	A–2–4 or A–1–b
Nicollet: 55	2–4	0–19	Loam	CL, ML, or CL–ML	A–4 or A–6
		19–39	Clay loam	CL or ML	A–6 or A–7
		39–60	Loam	CL	A–6
Okoboji:					
6	0–1	0–24	Silty clay loam	OH or MH	A–7
		24–48	Silty clay loam	CH or MH	A–7
		48–57	Silty clay loam	MH	A–7
		57–69	Clay loam	CL	A–6 or A–7
90	0–1	0–14	Mucky silt loam	OL or OH	A–7
		14–34	Silty clay loam	OH or CH	A–7
		34–60	Silty clay loam	OH or MH	A–7
T6	0–1	0-23	Silty clay loam	OH or MH	A–7
		23–42	Clay loam	CH or CL	A–7
		42–60	Sand and gravel	SW–SM or SM	A–1–b or A–2–4
Palms: 221	0–1	0–24	Muck	Pt	
		24–30	Mucky silt loam	OL or OH	A–7
		30–60	Silty clay loam	MH	A–7
Rolfe: 274	0–1	0–16	Silt loam, silty clay loam.	CL	A–6
		16–34	Silty clay, silty clay loam.	CH or MH	A–7
		34–42	Clay loam	CL	A–6 or A–7
		42–60	Sandy clay loam	CL	A–6 or A–7
Salida: 73C	>5	0–7	Gravelly sandy loam.	SC or SM	A–2–4
		7–13	Gravelly loamy sand.	SM or SC	A–2–4
		13–60	Sand and gravel	SM–SP, SM, or SP	A–1–b or A–2–4

significant in engineering—Continued

Percentage less than 3 inches passing sieve—				Liquid limit	Plasticity index	Permeability	Available water capacity	Reaction	Shrink-swell potential
No. 4 (4.7 mm)	No. 10 (2.0 mm)	No. 40 (0.42 mm)	No. 200 (0.074 mm)						
				Percent		*Inches per hour*	*Inches per inch of soil*	*pH*	
------	100	30–60	30–45	15–25	5–10	2.0–6.0	0.16–0.18	6.6–7.3	Low.
------	100	30–60	30–45	15–25	5–10	2.0–6.0	0.15–0.17	6.6–7.3	Low.
95–100	90–95	25–55	25–40	15–25	5–10	2.0–6.0	0.11–0.13	6.6–7.3	Very low.
70–90	50–70	20–30	5–20	NP	NP	6.0–20.0	0.02–0.04	7.9–8.4	Very low to none.
95–100	90–100	80–90	50–80	15–25	2–10	0.6–2.0	0.20–0.22	6.6–7.8	Moderate.
90–100	70–80	50–70	30–50	12–20	2–8	2.0–6.0	0.12–0.14	7.4–7.8	Low.
75–95	60–80	25–60	5–25	NP	NP	6.0–20.0	0.02–0.04	7.4–8.4	Very low to none.
100	98–100	85–95	65–80	30–50	20–40	0.6–2.0	0.20–0.22	7.9–8.4	Moderate to high.
100	98–100	80–90	65–80	30–50	20–40	0.6–2.0	0.15–0.19	7.9–8.4	Moderate to high.
95–100	92–100	80–90	65–80	30–50	20–40	0.6–2.0	0.14–0.16	7.9–8.4	Moderate to high.
100	95–100	80–95	50–80	30–40	11–20	0.6–2.0	0.20–0.22	6.6–7.8	Moderate.
95–100	80–100	45–75	30–45	25–35	5–15	2.0–6.0	0.12–0.14	7.4–7.8	Low.
75–95	60–80	25–50	5–25	5–25	NP	6.0–20	0.02–0.04	7.9–8.4	Very low.
100	95–100	80–95	60–85	35–50	15–30	0.6–2.0	0.20–0.22	7.9–8.4	High.
95–100	90–100	70–85	55–75	30–50	15–30	0.6–2.0	0.17–0.19	7.9–8.4	Moderate to high.
75–95	60–80	20–40	5–25	5–25	NP	6.0–20	0.02–0.04	7.9–8.4	Very low to none.
95–100	90–100	80–90	50–80	30–40	11–20	0.6–2.0	0.20–0.22	7.9–8.4	Moderate.
90–100	70–80	50–70	30–50	25–35	5–15	2.0–6.0	0.12–0.14	7.9–8.4	Low.
75–95	60–80	25–60	5–25	5–25	NP	6.0–20	0.02–0.04	7.9–8.4	Very low.
95–100	95–100	80–90	60–80	30–40	5–15	0.6–2.0	0.20–0.22	6.1–7.3	Moderate.
95–100	90–100	80–90	65–80	35–50	11–20	0.6–2.0	0.15–0.19	6.6–7.8	Moderate.
95–100	85–100	80–90	60–80	30–40	11–20	0.6–2.0	0.11–0.19	7.9–8.4	Moderate.
------	100	95–100	85–90	60–85	20–40	0.2–0.6	0.21–0.23	7.4–7.8	High.
------	100	95–100	85–90	50–80	20–40	0.2–0.6	0.18–0.20	7.4–7.8	High.
------	100	95–100	85–90	50–80	20–40	0.2–0.6	0.18–0.20	7.4–7.8	High.
95–100	90–100	80–90	65–80	35–50	15–25	0.2–0.6	0.14–0.16	7.9–8.4	Moderate.
------	100	100	95–100	41–55	15–25	0.6–2.0	0.22–0.26	7.4–7.8	Moderate.
------	100	95–100	85–90	50–80	20–40	0.2–0.6	0.18–0.20	7.4–7.8	High.
------	100	95–100	80–90	50–80	20–40	0.2–0.6	0.18–0.20	7.9–8.4	High.
------	100	95–100	85–90	60–85	20–40	0.2–0.6	0.21–0.23	7.4–7.8	High.
------	100	95–100	85–90	41–70	25–40	0.2–0.6	0.15–0.19	7.4–7.8	High.
75–95	60–80	25–60	5–25	NP	NP	6.0–20	0.02–0.04	7.9–8.4	Very low to none.
------	100	100	95–100	------	------	6.0–20	0.24–0.28	6.6–7.3	Moderate.
------	100	100	95–100	41–55	15–25	0.6–2.0	0.22–0.26	7.4–7.8	Moderate.
------	100	100	95–100	50–80	20–40	0.2–0.6	0.18–0.20	7.4–8.4	High.
------	100	90–100	70–90	30–40	15–30	0.6–2.0	0.22–0.24	6.6–7.3	Moderate.
------	100	95–100	90–100	50–80	25–40	0.06–0.2	0.11–0.13	5.6–6.0	High.
100	90–100	80–90	65–80	30–50	15–30	0.2–0.6	0.15–0.19	6.6–7.3	Moderate to high.
95–100	85–90	75–85	60–80	30–50	15–30	0.6–2.0	0.15–0.17	6.6–7.3	Moderate.
80–90	70–80	40–60	15–30	10–20	2–10	6.0–20	0.11–0.13	6.6–7.3	Low.
80–90	70–80	20–40	12–30	10–20	2–10	>20	0.08–0.10	7.9–8.4	Low.
75–90	50–75	20–40	5–30	NP	NP	>20	0.02–0.04	7.9–8.4	Very low to none.

TABLE 5.—*Estimated soil properties*

Soil series and map symbols	Depth to seasonal high water table	Depth from surface	USDA texture	Classification	
				Unified	AASHTO
	Feet	*Inches*			
Spillville: 485, 485B, C485 [1]	3–5	0–42	Loam	CL	A–6
		42–65	Loam, fine sandy loam.	CL, ML, or CL-ML	A–4 or A–6
*Storden: 62C, 62D, 62E, 62F, 639C, 639D, 639E. For Salida part of 639C, 639D and 639E, see Salida series.	>5	0–60	Loam	CL, ML, or CL-ML	A–4 or A–6
Talcot: 559 [1]	1–3	0–24	Clay loam	MH, ML, or CL	A–7
		24–39	Clay loam, loam, and sandy clay loam.	CL	A–6 or A–7
		39–60	Sand and gravel	SW–SM or SM	A–1–b or A–2–4
Truman: 339, 339B	>5	0–15	Silt loam	ML or CL	A–7
		15–54	Silt loam	CL	A–6
		54–66	Loam	CL–ML or CL	A–4
Wabash: 172 [1]	1–3	0–25	Silty clay	MH or CH	A–7
		25–70	Silty clay	CH	A–7
Wacousta: 506	0–1	0–13	Silty clay loam	OL, CL, or CH	A–7
		13–21	Silty clay loam	CL or CH	A–6 or A–7
		21–48	Silty clay loam	CL	A–6
		48–76	Silt loam	CL or CL–ML	A–6 or A–4
Wadena: 308	>5	0–12	Loam	CL, ML, or CL–ML	A–4 or A–6
		12–37	Loam	CL, ML, or CL–ML	A–6 or A–4
		37–60	Sand and gravel	SP–SM or SM	A–1–b or A–2–4
Waldorf: 390	1–3	0–20	Silty clay loam	MH	A–7
		20–35	Silty clay loam and silty clay.	MH	A–7
		35–45	Silty clay	MH	A–7
		45–65	Silty clay loam	MH	A–7
Watseka: 141 [1]	1–3	0–18	Loamy fine sand	SC or SM–SC	A–2–4 or A–4
		18–33	Loamy fine sand	SM, SC, or SM-SC	A–2–4 or A–4
		33–65	Fine and medium sand.	SP–SM, SM or SP	A–2–4
Webster: 107	1–3	0–17	Clay loam or silty clay loam.	ML, MH or CL	A–7
		17–36	Clay loam	CL	A–6 or A–7
		36–60	Clay loam	CL	A–6 or A–7

[1] Subject to flooding.

such as those shown in table 7, and other assistance furnished by the Iowa State Highway Commission.

Some terms used in this soil survey may have special meanings in soil science that may not be familiar to engineers. Many of these terms are defined in the Glossary.

Engineering classification systems

Most highway engineers classify soil material according to the system approved by the American Association of State Highway and Transportation Officials (AASHTO) (*1*). In this system soil materials are placed in seven principal groups based on field performance. The groups range from A–1, consisting of gravelly and coarse sandy soils of high bearing capacity, to A–7, consisting of clayey soils having low shear strength when wet.

Some engineers prefer to use the Unified Soil Classification System developed by the U.S. Army Corps of Engineers (*16*). This system is based on the texture and plasticity of soils and the performance of soils as material for engineering work. In this system, soil materials are classified as coarse-grained (eight classes), fine-grained (six classes), or highly organic (one class). An approximate classification can be made in the field. The soil series and land types in Palo Alto

significant in engineering—Continued

Percentage less than 3 inches passing sieve—				Liquid limit	Plasticity index	Permeability	Available water capacity	Reaction	Shrink-swell potential
No. 4 (4.7 mm)	No. 10 (2.0 mm)	No. 40 (0.42 mm)	No. 200 (0.074 mm)						
				Percent		*Inches per hour*	*Inches per inch of soil*	*pH*	
100	95–100	85–95	60–80	30–40	11–20	0.6–2.0	0.20–0.22	6.6–7.3	Moderate.
100	95–100	80–90	55–75	25–40	5–15	0.6–2.0	0.17–0.19	6.6–7.3	Moderate.
90–100	85–100	75–85	55–75	25–40	5–15	0.6–2.0	0.17–0.19	7.4–8.4	Moderate.
100	95–100	85–95	70–85	41–55	15–25	0.6–2.0	0.17–0.19	7.9–8.4	Moderate to high.
100	95–100	75–95	50–75	35–50	15–25	0.6–2.0	0.15–0.19	7.9–8.4	Moderate.
75–95	60–80	25–60	5–25	NP–20	NP–5	6.0–20	0.02–0.04	7.9–8.4	Very low to none.
------	100	95–100	75–95	41–50	11–25	0.6–2.0	0.22–0.24	6.6–7.3	Moderate.
------	100	95–100	80–98	30–40	11–20	0.6–2.0	0.20–0.22	6.6–7.3	Moderate.
------	100	90–100	50–65	20–35	5–10	0.6–2.0	0.17–0.19	7.4–7.8	Low to moderate.
------	100	98–100	95–100	60–85	40–60	<0.06	0.12–0.14	6.6–7.3	High.
------	100	98–100	95–100	50–75	30–50	<0.06	0.11–0.13	6.6–7.3	High.
------	100	95–100	80–95	41–65	20–40	0.2–0.6	0.21–0.23	6.6–7.8	Moderate to high.
------	100	95–100	75–95	35–55	15–30	0.2–0.6	0.18–0.20	7.9–8.4	Moderate to high.
100	95–100	90–95	70–90	30–40	15–25	0.2–0.6	0.18–0.20	7.9–8.4	Moderate.
95–100	90–100	85–90	60–85	25–40	5–20	0.6–2.0	0.20–0.22	7.9–8.4	Moderate.
100	90–100	75–90	50–75	25–40	5–15	2.0–6.0	0.20–0.22	6.6–7.3	Moderate.
95–100	80–100	60–80	50–65	25–40	5–15	2.0–6.0	0.17–0.19	6.6–7.3	Moderate to low.
75–95	60–80	25–60	5–25	NP	NP	6.0–20	0.02–0.04	7.4–7.8	Very low to none.
100	100	98–100	90–100	50–65	15–25	0.2–0.6	0.21–0.23	6.6–7.3	High.
100	100	98–100	90–100	50–65	15–30	0.2–0.6	0.18–0.20	6.6–7.3	High.
100	100	98–100	90–100	55–75	15–30	0.06–0.2	0.11–0.13	6.6–7.3	High.
100	100	98–100	90–100	50–65	15–30	0.2–0.6	0.18–0.20	7.4–8.4	High.
98–100	95–100	40–70	15–40	15–30	5–10	2.0–6.0	0.10–0.12	5.6–6.5	Low.
95–100	90–100	40–70	10–35	15–30	2–10	6.0–20	0.09–0.11	5.6–6.0	Very low to none.
95–100	90–100	40–70	5–20	10–30	5–10	6.0–20	0.05–0.07	6.1–6.5	Very low to none.
100	95–100	90–95	70–90	41–60	15–30	0.2–0.6	0.17–0.19 or 0.21–0.23	6.6–7.3	Moderate to high.
95–100	95–100	80–95	60–80	30–50	15–30	0.2–0.6	0.15–0.19	6.6–7.8	Moderate to high.
95–100	95–100	75–90	60–75	30–50	15–30	0.2–0.6	0.14–0.16	7.4–7.8	Moderate.

[2] Nonplastic.

County have been classified by the AASHTO and Unified Systems in table 5.

Estimated soil properties significant in engineering

In table 5, the soil series in Palo Alto County are listed, and estimates of the behavior of each soil are given. Some of the estimates were made on the basis of tests and samples from four soil series. The results of those tests are shown in table 7. For those soils not listed in table 7, properties were estimated by using data from those series or similar series in other counties in Iowa.

Permeability is estimated for each soil as it occurs in place. The estimates were based on soil structure and porosity and were compared to permeability rates for undisturbed cores of similar soil material.

The available moisture capacity is expressed in this table in inches per inch of soil depth. It is the approximate amount of capillary water in the soil when it is wet to field capacity. When the soil is air-dry, this amount of water will wet the material described to a depth of 1 inch without deeper penetration.

Reaction, or pH, is the degree of acidity or alkalinity. The pH of a neutral soil is 6.6 to 7.3, of an acid soil is less than 6.6, and of an alkaline soil is more than 7.3. Many soils in Palo Alto County are neutral or alkaline.

TABLE 6.—*Engineering*

[An asterisk in the first column indicates that at least one mapping unit in the series is made up of two or more kinds of soil. other series in the first

Soil series and map symbols	Degree and kind of limitation for—				Suitability as source of—
	Septic tank absorption fields	Sewage lagoons	Sanitary landfill [1]	Local roads and streets	Road fill
Biscay: 259	Severe: seasonal high water table; danger of contamination of ground water.	Severe: seasonal high water table; rapid permeability in substratum; danger of contamination of ground water.	Severe: poorly drained; rapid to very rapid permeability in sand and gravel substratum; seasonal high water table; danger of contamination of ground water.	Severe: poorly drained; seasonal high water table; high in organic matter in upper 2 feet.	Poor: poorly drained; low strength in upper 3 feet.
Blue Earth: 511	Severe: seasonal high water table; subject to ponding in wet seasons.	Severe: very high in organic matter; seasonal high water table; subject to ponding.	Severe: very poorly drained; subject to ponding; seasonal high water table.	Severe: very poorly drained; seasonal high water table; subject to ponding; low strength.	Poor: very poorly drained; low strength.
Calco: 733	Severe: seasonal high water table; subject to flooding in most places; moderately slow permeability.	Severe: high in organic matter; frequently flooded in places; seasonal high water table.	Severe: poorly drained; subject to flooding; seasonal high water table.	Severe: poorly drained; seasonal high water table; high in organic matter in upper 3 feet; subject to flooding; high shrink-swell potential; low strength.	Poor: low strength; poorly drained; high shrink-swell potential.
Canisteo: 507	Severe: seasonal high water table.	Severe: seasonal high water table.	Severe: poorly drained; seasonal high water table.	Severe: poorly drained; seasonal high water table; high in organic matter in upper 1½ to 2 feet; low strength.	Poor: poorly drained; low strength.
*Clarion: 138B, 138C, 138C2, 138D2, 181B, 181C2, 638B. For Estherville part of 181B and 181C2, see Estherville 34, 34B, 34C2; for Storden part of 638B, see Storden series.	Slight if slope is 2 to 9 percent, moderate if 9 to 14, severe if more than 14.	Moderate if slope is 2 to 9 percent, severe if more than 9; moderate permeability.	Slight: [2] All features favorable.	Slight if slope is 2 to 9 percent, moderate if more than 9.	Fair: low strength; moderate shrink-swell potential.
*Colo: 133, 133B, 585B. For Spillville part of 585B, see Spillville series.	Severe: seasonal high water table; in most places subject to flooding; moderately slow permeability.	Severe: high in organic matter; frequently flooded in places; seasonal high water table.	Severe: subject to flooding; poorly drained; seasonal high water table.	Severe: poorly drained; seasonal high water table; subject to flooding.	Poor: low strength; poorly drained; high shrink-swell potential.

interpretations

Because these soils have different properties and limitations, it is necessary to follow carefully the instructions for referring to column of this table]

Suitability as source of—Continued		Soil features affecting—				
Sand and gravel	Topsoil	Pond reservoir areas	Embankments, dikes, and levees	Drainage of cropland and pasture	Irrigation	Terraces and diversions
Fair below a depth of about 3 feet; mixed sand and gravel; high water table may hinder excavation.	Poor: poorly drained.	Nearly level; coarse textured; porous substratum.	High in organic matter to a depth of about 2 feet; substratum is stable but porous.	Poorly drained; moderate permeability above coarse substratum; sand and gravel in substratum.	Moderate available water capacity; medium intake rate; nearly level.	Nearly level; no terraces needed.
Not suitable	Poor: very poorly drained.	Depressional; seasonal high water table; some areas suitable for dugout or pit pond.	Not suitable to a depth of at least 1½ feet; poor stability and compaction; high compressibility below 1½ feet.	Very poorly drained; moderately slow permeability; outlets sometimes difficult to obtain.	High available water capacity; medium intake rate; depressional.	Depressional; no terraces needed.
Not suitable	Poor: poorly drained.	Nearly level; seasonal high water table; some areas suitable for dugout or pit pond.	High in organic matter to a depth of 3 feet or more; fair to poor stability; poor workability.	Poorly drained; moderately slow permeability; in places outlets submerged; frequently flooded in places.	High available water capacity; medium intake rate; frequently flooded in places; nearly level.	Nearly level; no terraces needed.
Not suitable	Poor: poorly drained.	Nearly level; seasonal high water table; some areas suitable for dugout or pit pond.	Fair suitability and compaction below surface layer; low permeability when compacted; low strength.	Poorly drained; moderate permeability; outlets not adequate in places.	High available water capacity; medium intake rate; nearly level.	Nearly level; no terraces needed.
Not suitable	Good if slope is 2 to 9 percent, fair if more than 9.	Moderate permeability unless compacted; occasional pockets of sand or gravel.	Good stability; a few stones or boulders; moderate shrink-swell potential.	Well drained; no drainage needed.	High available water capacity; medium intake rate; gently sloping to strongly sloping.	Complex slopes in places; features favorable except for occasional stones or boulders.
Not suitable	Poor: poorly drained.	Nearly level; seasonal high water table; some areas suitable for dugout or pit ponds.	High in organic matter to a depth of 3 feet or more; fair to poor stability; poor workability; poor embankment foundation.	Poorly drained; moderately slow permeability; in places outlets submerged; frequently flooded in places.	High available water capacity; medium intake rate; frequently flooded in places; nearly level or gently sloping.	Nearly level to gently sloping; no terraces needed.

TABLE 6.—*Engineering*

Soil series and map symbols	Degree and kind of limitation for—				Suitability as source of—
	Septic tank absorption fields	Sewage lagoons	Sanitary landfill [1]	Local roads and streets	Road fill
Crippin: 655	Severe: seasonal high water table.	Severe: seasonal high water table.	Moderate: [2] somewhat poorly drained; occurs in small areas.	Moderate: somewhat poorly drained; high water table in wet periods; high in organic matter to a depth of about 1½ feet; moderate shrink-swell potential.	Fair: low strength; somewhat poorly drained.
Cylinder: 203	Severe: seasonal high water table; danger of contamination of ground water.	Severe: rapid permeability in substratum; seasonal high water table.	Severe: rapid permeability in sand and gravel substratum; danger of contamination of ground water.	Moderate: somewhat poorly drained; high water table in wet periods; high in organic matter to a depth of about 1½ feet.	Fair: low strength in upper 3 feet; somewhat poorly drained.
Dickman: 324, 324B.	Slight: danger of contamination of ground water.	Severe: rapid permeability.	Severe: too sandy to restrict movement of leachate; rapid permeability to about 4 feet; danger of contamination of ground water.	Slight: features favorable.	Good: features favorable.
Estherville:					
34, 34B, 34C2	Slight: danger of contamination of ground water.	Severe: very rapid permeability below 15 to 30 inches.	Severe: rapid to very rapid permeability in sand and gravel substratum; danger of pollution of ground water.	Slight: features favorable.	Good: features favorable.
72, 72B	Slight: danger of contamination of ground water.	Severe: very rapid permeability below 2 feet.	Severe: rapid to very rapid permeability in sand and gravel substratum; danger of pollution of ground water.	Slight: features favorable.	Good: features favorable.
Farrar: 253C	Slight: features favorable.	Moderate: moderately rapid permeability in top 30 inches; moderate permeability below 30 inches; 5 to 9 percent slopes.	Slight: [2] features favorable below 2½ feet.	Slight: features favorable.	Good in upper 2½ feet; fair below: low strength.

interpretations—Continued

Suitability as source of—Continued		Soil features affecting—				
Sand and gravel	Topsoil	Pond reservoir areas	Embankments, dikes, and levees	Drainage of cropland and pasture	Irrigation	Terraces and diversions
Not suitable	Good: surface is often calcareous.	Nearly level; moderate permeability unless compacted.	Fair to good stability; high in organic matter to a depth of about 1½ feet; material below 1½ feet compacts to high density.	Somewhat poorly drained; moderate permeability.	High available water capacity; medium intake rate; nearly level or gently sloping.	Nearly level; no terraces needed; features favorable; a few stones or boulders.
Suitable below a depth of 3 feet; mixed sand and gravel variable quality.	Good: area may be hard to reclaim.	Nearly level; porous substratum.	Good stability especially in the substratum; pervious when compacted.	Somewhat poorly drained; moderate permeability in upper part; rapid permeability in the underlying sand and gravel.	Moderate available water capacity; medium intake rate; nearly level.	Nearly level; no terraces needed.
Not suitable for gravel; fair suitability for poorly graded fine and medium sands; not suitable for concrete.	Good: features favorable.	Porous substratum.	Fair stability above 4 feet; underlying material, good stability; underlying material, generally moderate permeability when compacted.	Somewhat excessively drained; no drainage needed.	Moderate available water capacity; rapid intake rate; high erodibility; nearly level or gently sloping.	Highly erodible on slopes; difficult to maintain ridge and channel; subject to piping; difficult to vegetate.
Suitable below a depth of 15 to 30 inches; mixed sand and gravel; some areas contain considerable fines.	Fair: thin layer; area hard to reclaim.	Porous substratum.	Good stability, especially below 15 to 30 inches; substratum pervious when compacted.	Excessively drained; no drainage needed.	Very low available water capacity; rapid intake rate; nearly level to moderately sloping.	Nearly level to moderately sloping; sand and gravel at 15 to 30 inches; difficult to vegetate.
Suitable below a depth of about 2 feet; mixed sand and gravel; some areas contain considerable fines.	Fair: thin layer; area hard to reclaim.	Porous substratum.	Good stability, especially below 2 feet; substratum pervious when compacted.	Somewhat excessively drained; no drainage needed.	Low available water capacity; moderate to rapid intake rate; nearly level or gently sloping.	Nearly level to gently sloping; sand and gravel at about 2 feet; difficult to vegetate.
Not suitable for gravel; fair suitability for poorly graded fine and medium sand in upper 30 inches; not suitable for concrete.	Good: features favorable.	Upper 30 inches porous.	Good stability; a few stones or boulders in substratum; moderate shrink-swell potential in substratum.	Somewhat excessively drained; no drainage needed.	Moderate available water capacity; rapid intake rate above 30 inches; high erodibility on stronger slopes; moderately sloping.	Highly erodible on slopes; difficult to maintain ridge and channel; subject to piping in surface layer; somewhat difficult to vegetate.

TABLE 6.—*Engineering*

Soil series and map symbols	Degree and kind of limitation for—				Suitability as source of—
	Septic tank absorption fields	Sewage lagoons	Sanitary landfill [1]	Local roads and streets	Road fill
Flagler: 823, 823B	Slight: danger of contamination of ground water.	Severe: moderately rapid to rapid permeability.	Severe: moderately rapid to rapid permeability; sand and gravel too porous to restrict movement of leachate; danger of pollution of ground water.	Slight: features favorable.	Good: features favorable.
Hanska: 150	Severe: seasonal high water table; danger of contamination of ground water; some areas subject to flooding.	Severe: seasonal high water table; rapid permeability in substratum.	Severe: poorly drained; seasonal high water table; rapid to very rapid permeability in sand and gravel substratum; danger of pollution of ground water.	Severe: poorly drained; seasonal water table; high in organic matter in upper 1½ feet.	Poor: poorly drained.
Harps: 95	Severe: seasonal high water table; generally adjacent to very wet soils in depressions.	Severe: seasonal high water table.	Severe: poorly drained; seasonal high water table.	Severe: poorly drained; seasonal high water table; low strength.	Poor: low strength; poorly drained.
Linder: 224	Severe: seasonal high water table; danger of contamination of ground water.	Severe: rapid permeability in substratum; seasonal high water table.	Severe: seasonal high water table; rapid to very rapid permeability in sand and gravel substratum.	Moderate: somewhat poorly drained; high water table in wet periods.	Fair: somewhat poorly drained.
Marsh: 354. No interpretations—properties too variable.					
Mayer:					
658	Severe: seasonal high water table; danger of contamination of ground water.	Severe: seasonal high water table; rapid permeability in substratum.	Severe: poorly drained; seasonal high water table; rapid to very rapid permeability in substratum.	Severe: poorly drained; seasonal high water table; high in organic matter to a depth of about 2 feet.	Poor: poorly drained.
895	Severe: seasonal high water table; danger of contamination of ground water.	Severe: seasonal high water table; rapid permeability in substratum.	Severe: poorly drained; seasonal high water table; rapid to very rapid permeability in substratum.	Severe: poorly drained; seasonal high water table; high in organic matter in upper 1½ feet.	Poor: poorly drained.

interpretations—Continued

Suitability as source of—Continued		Soil features affecting—				
Sand and gravel	Topsoil	Pond reservoir areas	Embankments, dikes, and levees	Drainage of cropland and pasture	Irrigation	Terraces and diversions
Suitable below a depth of about 3 feet; mixed sand and gravel, variable quality. Fair in upper part for poorly graded fine and medium sand.	Good: some coarse fragments.	Nearly level to gently sloping; porous material.	Good stability; pervious when compacted.	Somewhat excessively drained; no drainage needed.	Moderate available water capacity; rapid intake rate; nearly level or gently sloping; high erodibility.	Highly erodible on slopes; difficult to maintain ridge and channel; sand and gravel at about 3 feet; somewhat difficult to vegetate.
Suitable below a depth of about 2 feet; generally mixed sand and gravel; high water table may hinder excavation.	Poor: poorly drained.	Coarse textured, porous substratum.	High in organic matter in upper 1½ feet; substratum stable but pervious.	Poorly drained; sand and gravel in substratum; danger of over draining; moderately rapid permeability.	Low available water capacity; medium intake rate; nearly level.	Nearly level; no terraces needed.
Not suitable	Poor: poorly drained.	Nearly level; seasonal high water table.	Medium to low shear strength; medium compressibility; good compaction characteristics.	Poorly drained; moderate permeability; outlets not readily available.	High available water capacity; medium intake rate; nearly level.	Nearly level; no terraces needed.
Suitable below a depth of about 2 feet; generally mixed sand and gravel; quality variable.	Good: area hard to reclaim.	Nearly level; coarse textured, porous substratum.	Good stability, especially below a depth of 2 feet; substratum stable but pervious when compacted.	Somewhat poorly drained; sand and gravel at about 2 to 2½ feet.	Low available water capacity; medium intake rate; nearly level.	Nearly level; no terraces needed.
Suitable below a depth of about 2½ feet; mixed sand and gravel; high water table may hinder excavation.	Poor: poorly drained.	Nearly level; coarse textured, porous substratum.	High in organic matter to a depth of about 2 feet; substratum stable but pervious.	Poorly drained; sand and gravel in substratum; danger of over drainage; moderate permeability in upper part.	Moderate available water capacity; medium intake rate; nearly level.	Nearly level; no terraces needed.
Suitable below a depth of about 2½ feet; mixed sand and gravel; high water table may hinder excavation.	Poor: poorly drained.	Nearly level; coarse textured, porous substratum.	High in organic matter in upper 1½ feet; substratum stable but pervious when compacted.	Poorly drained; sand and gravel in substratum; danger of over draining; moderate permeability in upper part.	Low to moderate available water capacity; medium intake rate; nearly level.	Nearly level; no terraces needed.

TABLE 6.—*Engineering*

Soil series and map symbols	Degree and kind of limitation for—				Suitability as source of—
	Septic tank absorption fields	Sewage lagoons	Sanitary landfill [1]	Local roads and streets	Road fill
Nicollet: 55	Severe: seasonal high water table.	Severe: high water table in wet periods.	Moderate: [2] somewhat poorly drained.	Moderate: somewhat poorly drained; high in organic matter to a depth of 1½ feet.	Fair: low strength; somewhat poorly drained.
Okoboji:					
6	Severe: frequent high water table; subject to ponding; moderately slow permeability.	Severe: highly organic surface layer; frequent high water table.	Severe: very poorly drained; frequent high water table; subject to ponding.	Severe: very poorly drained; frequent high water table; subject to ponding.	Poor: low strength; very poorly drained.
90	Severe: frequent high water table; subject to ponding; moderately slow permeability.	Severe: very highly organic surface layer; frequent high water table.	Severe: very poorly drained; frequent high water table; subject to ponding.	Severe: very poorly drained; frequent high water table; subject to ponding.	Poor: low strength; very poorly drained.
T6	Severe: frequent high water table; subject to ponding; moderately slow permeability; danger of contamination of ground water.	Severe: highly organic surface layer; frequent high water table; rapid permeability in substratum.	Severe: very poorly drained; frequent high water table; subject to ponding; rapid to very rapid permeability in sand and gravel substratum.	Severe: very poorly drained; seasonal high water table; some ponding after heavy rains in wet periods.	Poor: low strength; very poorly drained.
Palms: 221	Severe: frequent high water table; subject to ponding.	Severe: very highly organic surface layer; frequent high water table.	Severe: very poorly drained; frequent high water table; subject to ponding.	Severe: very poorly drained; frequent high water table; ponding.	Poor: low strength; very poorly drained.
Rolfe: 274	Severe: frequent high water table; subject to ponding; slow permeability.	Moderate: seasonal high water table; subject to ponding.	Severe: very poorly drained; frequent high water table; subject to ponding.	Severe: very poorly drained; subject to ponding; frequent high water table.	Poor: low strength; very poorly drained.

interpretations—Continued

Suitability as source of—Continued		Soil features affecting—				
Sand and gravel	Topsoil	Pond reservoir areas	Embankments, dikes, and levees	Drainage of cropland and pasture	Irrigation	Terraces and diversions
Not suitable	Good: features favorable.	Nearly level; moderate permeability when not compacted.	Fair to good stability; high in organic matter to a depth of about 1½ feet; material below 1½ feet compacts to a high density.	Somewhat poorly drained; moderate permeability.	High available water capacity; medium intake rate; nearly level.	Nearly level; no terraces needed; features favorable; a few stones or boulders.
Not suitable	Poor: very poorly drained.	Depressional; frequent high water table; generally suitable for dugout or pit ponds.	High in organic matter to a depth of about 3 feet; fair to poor stability; poor compaction; high compressibility.	Very poorly drained; moderately slow permeability; surface intakes sometimes needed; outlets may require deep cuts.	High available water capacity; medium intake rate; nearly level.	Depressions; no terraces needed.
Not suitable	Poor: very poorly drained.	Depressional; frequent high water table; generally suitable for dugout or pit ponds.	Very high in organic matter to a depth of 3 feet, especially in the top foot; fair to poor stability; poor compaction and high compressibility.	Very poorly drained; moderately slow permeability; surface intakes needed; outlets may require deep cuts.	High available water capacity; medium intake rate; nearly level.	Depressions; no terraces needed.
Suitable below a depth of about 3 feet or more; generally mixed sand and gravel; high water table may hinder excavation.	Poor: very poorly drained.	Depressional; coarse textured, porous substratum.	High in organic matter to a depth of about 3 feet; substratum stable but pervious.	Very poorly drained; moderately slow permeability; surface intakes sometimes needed; outlets may require deep cuts; sand and gravel substratum.	High available water capacity; medium intake rate; nearly level.	Depressions; no terraces needed.
Not suitable	Poor: very poorly drained.	Depressional; frequent high water table; generally suitable for dugout or pit ponds.	Not suitable	Very poorly drained; moderate permeability in mineral part; open ditches or surface intake needed; outlets may require deep cuts.	High available water capacity; medium intake rate; nearly level.	Depressions; no terraces needed.
Not suitable	Poor: very poorly drained.	Depressional; high water table; generally suitable for dugout or pit ponds.	Medium to low shear strength; low compacted permeability; fair compaction characteristics.	Very poorly drained; slow permeability; blind intakes, open ditches, or surface intake needed; outlets may require deep cuts.	High available water capacity; slow intake rate; nearly level.	Depressions; no terraces needed.

TABLE 6.—*Engineering*

Soil series and map symbols	Degree and kind of limitation for—				Suitability as source of—
	Septic tank absorption fields	Sewage lagoons	Sanitary landfill [1]	Local roads and streets	Road fill
Salida: 73C	Slight if slope is 2 to 9 percent, moderate if more than 9 percent; danger of contamination of ground water.	Severe: rapid to very rapid permeability.	Severe: rapid to very rapid permeability; danger of contamination of ground water.	Slight if slope is 5 to 9 percent; moderate if more than 9 percent.	Good: features favorable.
Spillville: 485, 485B, C485.	Severe: some areas subject to flooding; seasonal high water table.	Severe: subject to flooding; seasonal high water table.	Severe: subject to flooding; coarse material below 4 feet in places; seasonal high water table.	Severe: subject to flooding; high in organic matter to a depth of about 3 feet.	Fair: low strength; moderate shrink-swell potential; moderately well drained to somewhat poorly drained.
*Storden: 62C, 62D, 62E, 62F, 639C, 639D, 639E. For Salida part of 639C, 639D, and 639E, see Salida series.	Slight if slope is 2 to 9 percent, moderate if 9 to 14 percent, severe if more than 14 percent.	Moderate if slope is 2 to 9 percent, severe if more than 9 percent.	Slight [2] if slope is less than 14 percent, moderate if 14 to 25 percent, severe if more than 25 percent.	Moderate if slope is 2 to 14 percent; some stones and boulders; low strength; severe if more than 14 percent.	Fair: low strength.
Talcot: 559	Severe: seasonal high water table; danger of contamination of ground water.	Severe: seasonal high water table; rapid permeability in substratum.	Severe: poorly drained; seasonal high water table; rapid to very rapid permeability in sand and gravel substratum; danger of contamination of ground water.	Severe: poorly drained; seasonal high water table; high in organic matter to a depth of about 2 feet.	Poor: low strength in upper 3 feet; poorly drained.
Truman: 339, 339B.	Slight: features favorable.	Moderate: moderate permeability; 0 to 5 percent slopes.	Moderate: [3] substratum may be rapidly permeable below 6 feet; danger of contamination of ground water.	Moderate: low strength.	Fair: low strength; moderate shrink-swell potential.
Wabash: 172	Severe: seasonal high water table; very slow permeability.	Severe: seasonal high water table; subject to flooding.	Severe: very poorly drained; high water table; subject to flooding.	Severe: very poorly drained; seasonal high water table; subject to flooding; low strength.	Poor: high shrink-swell potential; low strength; very poorly drained.
Wacousta: 506	Severe: frequent high water table; subject to ponding.	Severe: frequent high water table; subject to ponding.	Severe: very poorly drained; frequent high water table; subject to ponding.	Severe: very poorly drained; frequent high water table; undrained areas subject to ponding.	Poor: low strength; moderate or high shrink-swell potential; very poorly drained.

interpretations—Continued

Suitability as source of—Continued		Soil features affecting—				
Sand and gravel	Topsoil	Pond reservoir areas	Embankments, dikes, and levees	Drainage of cropland and pasture	Irrigation	Terraces and diversions
Fair to good; mixed sand and gravel.	Poor: gravelly sandy loam; thin layer; hard to reclaim area.	Coarse textured, porous substratum.	Fair stability; good strength and compaction characteristics; pervious layers; some stones and boulders.	Excessively drained; no drainage needed.	Very low available water capacity; rapid intake rate; moderately sloping or strongly sloping.	Irregular topography; shallow to sand and gravel; high erodibility on steeper slopes; very droughty; difficult to vegetate.
Not suitable	Good: features favorable.	Nearly level or gently sloping; moderate permeability.	Fair stability; fair compaction below a depth of 2 or 3 feet; poor embankment foundation.	Moderately well to somewhat poorly drained; subject to flooding; no drainage needed in most places.	High available water capacity; medium intake rate; subject to flooding; nearly level or gently sloping.	Nearly level or gently sloping; no terraces needed.
Not suitable	Good if slope is 2 to 9 percent, fair if 9 to 14 percent, poor if more than 14 percent.	Moderate permeability; occasional pockets of sand or gravel.	Good stability; good compaction characteristics; slow permeability when compacted.	Somewhat excessively drained; drainage not needed.	High available water capacity; medium intake rate; gently sloping to very steep.	Gently sloping to very steep; irregular topography; occasional stones and boulders; difficult to establish vegetation.
Suitable below a depth of about 3 feet; mixed sand or gravel; high water table may hinder excavation.	Poor: poorly drained.	Coarse textured, porous substratum.	High in organic matter to a depth of about 2 feet; substratum stable but pervious.	Poorly drained; moderate permeability above the coarse substratum; sand and gravel in the substratum.	Moderate available water capacity; medium intake rate; nearly level.	Nearly level; no terraces needed.
Not suitable	Good: features favorable.	Piping hazard; semi-pervious to impervious when compacted.	Poor stability; good to poor compaction characteristics; piping hazard.	Well drained; drainage not needed.	High available water capacity; medium intake rate; nearly level or gently sloping.	Nearly level or gently sloping.
Not suitable	Poor: very poorly drained; high clay content.	Nearly level; very slow permeability; some areas suitable for dugout or pit ponds; subject to flooding.	Fair stability; poor compaction; high compressibility; high in organic matter to a depth of 3 feet or more; low strength.	Very poorly drained; subject to flooding; very slow permeability.	Moderate available water capacity; slow intake rate; subject to flooding; nearly level.	Nearly level; no terraces needed.
Not suitable	Poor: very poorly drained.	Nearly level; some areas suitable for dugout or pit ponds.	Poor workability and compaction; low strength.	Very poorly drained; open intake or surface ditches needed; deep cuts needed in places to obtain outlets; moderate to moderately slow permeability.	High available water capacity; medium intake rate; nearly level.	Depressional; no terraces needed.

TABLE 6.—*Engineering*

Soil series and map symbols	Degree and kind of limitation for—				Suitability as source of—
	Septic tank absorption fields	Sewage lagoons	Sanitary landfill [1]	Local roads and streets	Road fill
Wadena: 308	Slight: danger of contamination of ground water.	Severe: rapid permeability in substratum.	Severe: rapid permeability in sand and gravel substratum; danger of contamination of ground water.	Moderate: low strength; features favorable below a depth of 3 feet.	Fair above a depth of about 3 feet; low strength; good below 3 feet.
Waldorf: 390	Severe: moderately slow to slow permeability; seasonal high water table.	Severe: seasonal high water table.	Severe: poorly drained; seasonal high water table.	Severe: poorly drained; seasonal high water table; high in organic matter to a depth of about 2 feet.	Poor: low strength; high shrink-swell potential; poorly drained.
Watseka: 141	Severe: seasonal high water table; danger of contamination of ground water.	Severe: seasonal high water table; subject to flooding; rapid permeability.	Severe: seasonal high water table; rapid permeability; sands too porous to restrict movement of leachate; subject to flooding; danger of pollution of ground water.	Severe: subject to flooding; seasonal high water table.	Fair: somewhat poorly drained.
Webster: 107	Severe: seasonal high water table.	Severe: seasonal high water table.	Severe: poorly drained; seasonal high water table.	Severe: poorly drained; high in organic matter to a depth of 1½ to 2 feet.	Poor: low strength; high shrink-swell potential; poorly drained.

[1] Onsite study is needed of the underlying strata, the water table, and the hazards of aquifer pollution and drainage into ground water in landfill deeper than 5 or 6 feet.

The shrink-swell potential indicates the change in volume to be expected of soil material with changes in moisture content. It is estimated mainly on the basis of the kind and amount of clay present.

Bedrock does not occur in the county above depths normally investigated during the soil survey.

Engineering interpretations

In table 6 the soils in each series are rated for their suitability as a source of topsoil, sand and gravel, and road fill. The suitability of soil material for road fill depends largely on the density that can be obtained by compacting the material. Density affects the rigidity, flexibility, and load-bearing properties of the soil when used as subgrade fill for paved roads and as surfacing material for unpaved roads. Shrink-swell potential is also a factor in evaluating material for road fill. Impermeable material is also rated as to how impervious it becomes when compacted.

Soil features affecting the use of soils for farm ponds, agricultural drainage, irrigation, and terraces and diversions are given in table 6. Features that have an adverse affect on these practices generally are listed, but beneficial features are listed for some practices. Special features affecting highway construction are discussed elsewhere in this section.

Also rated in table 6 is the degree of limitations of each soil series for septic-tank absorption fields, sewage lagoons, sanitary landfill, and local roads and streets.

For septic-tank disposal fields, the soils are rated for their ability to absorb sewage effluent over a long period. Before a septic tank and field are installed, however, a percolation test should be made at the site. A sewage system that is close to a well or stream may contaminate the water.

Soils are rated according to their potential for sanitary landfills. Features that are important in this county are depth to water table, soil drainage class, soil

interpretations—Continued

Suitability as source of—Continued		Soil features affecting—				
Sand and gravel	Topsoil	Pond reservoir areas	Embankments, dikes, and levees	Drainage of cropland and pasture	Irrigation	Terraces and diversions
Suitable below a depth of about 3 feet; generally mixed sand and gravel.	Good: area may be hard to reclaim.	Nearly level; coarse textured, porous substratum.	Good stability; substratum pervious when compacted.	Well drained; no drainage needed.	Moderate available water capacity; medium intake rate; nearly level.	Nearly level; no terraces needed.
Not suitable	Poor: poorly drained.	Nearly level; moderately slow to slow permeability; seasonally high water table; some sites suitable for dugout or pit ponds.	Fair stability on level slopes; poor compaction; high compressibility and shrink-swell potential.	Poorly drained; moderately slow to slow permeability.	High available water capacity; slow intake rate; nearly level.	Nearly level; no terraces needed.
Poor for gravel; generally small quantity; fair to good for poorly graded sands; some areas high in fines.	Poor: loamy fine sand to sand texture.	Coarse textured, porous material.	Fair stability, but porous.	Somewhat poorly drained; rapid permeability.	Low available water capacity; rapid intake rate; nearly level.	Nearly level; no terraces needed.
Not suitable	Poor: poorly drained.	Nearly level; seasonal high water table; some sites suitable for dugout or pit ponds.	Fair stability and compaction below $1\frac{1}{2}$ to 2 feet; slow permeability when compacted.	Poorly drained; outlets not adequate in places; moderate or moderately slow permeability.	High available water capacity; medium intake rate; nearly level.	Nearly level; no terraces needed.

[2] Probably potentially high to a depth of 12 feet or more.
[3] Probably potentially moderate below a depth of about 6 feet.

texture, slope, permeability, and depth to sand and gravel.

For determining sites for sanitary landfills, the data given cannot be a substitute for geologic investigations, because these interpretations are based on borings to a depth of 5 to 6 feet, whereas sanitary landfills are made to greater depths. Yet these interpretations can be useful. They can, for example, guide geologic investigations in areas already determined to have serious soil limitations.

Engineering test data

Soil samples were taken, by horizon, from five series and tested according to standard AASHTO procedures to help evaluate the soils for engineering purposes. The tests were made by the Iowa State Highway Commission. The data in table 7 apply to samples taken from a depth of 5 feet or less and do not represent materials at a greater depth.

The relationship between the moisture content and the density of compacted soil material is shown in table 7 in the columns headed Moisture density. The density, or unit weight, of the compacted dry soil increases as the content of moisture increases until the optimum content is reached. After that, the density decreases with each increase in moisture content. The highest density obtained in the test is at the optimum moisture content and is the maximum density. As a rule, optimum stability is obtained as the soil is compacted to about the maximum density when the soil is at or near the optimum moisture content.

The liquid limit and the plasticity index indicate the effect of moisture on the consistence of the soil material. As the moisture content of a dry clayey soil is increased, the material changes from a semisolid state to a plastic state. As the moisture content is further increased, the material changes from a plastic to a liquid state. The plastic limit is the moisture content at which

TABLE 7.—*Engineering*

[Tests performed by Iowa State Highway

Soil name and location	Parent material	Report No. AAD6—	Depth	Horizon	Moisture density [1]		Mechanical analysis [2]		
					Maximum dry density	Optimum moisture	Percentage passing sieve—		
							1½-in	1-in	¾-in
			Inches		*Percent*	*Percent*			
Biscay clay loam:									
1,000 feet west and 95 feet south of northeast corner of NE¼NW¼ sec. 7, T. R. 95 N., R. 32 W. Higher content of sand than modal.	Alluvium.	3368	7–16	A1	94	21	------	------	------
		3369	31–39	B22g	115	13	------	------	------
		3370	50–60	IICg	123	12	------	100	99
Crippin loam:									
44 feet south and 610 feet west of northeast corner of NW¼ sec. 21, T. 97 N., R. 32 W. (Modal)	Friable, calcareous loam or clay loam till of late Wisconsin age.	3152	0–7	Ap	99	21	------	------	------
		3153	20–27	B2	110	16	------	------	------
		3154	35–60	C	119	13	------	------	100
Linder loam:									
40 feet east and 110 feet south of northwest corner of NE¼ sec. 29, T. 96 N., R. 31 W. (Modal)	Calcareous silt.	3374	0–7	Ap	91	23	------	------	------
		3375	13–24	B2	118	13	------	------	------
		3376	24–28	IIC	125	11	------	100	99
Truman silt loam:									
750 feet south of northwest corner of sec. 33, T. 97 N., R. 32 W. (Modal)	Calcareous silt.	3377	8–15	A1	92	25	------	------	------
		3378	24–33	B21	100	21	------	------	------
		3379	54–66	C	104	17	------	------	------

[1] Based on AASHTO Designation T 99 (*1*).

[2] Mechanical analyses according to the AASHTO Designation T 88. Results by this procedure frequently may differ somewhat from results that would have been obtained by the soil survey procedure of the Soil Conservation Service (SCS). In the AASHTO procedure, the fine material is analyzed by the hydrometer method and the various grain-sized fractions are calculated on the basis of all the material, including that coarser than 2 millimeters in diameter. In the SCS soil survey procedure, the fine material is analyzed by the pipette method and the material coarser than 2 millimeters in diameter is excluded from calculations of grain-sized fractions. The mechanical analyses used in this table are not suitable for use in naming textural classes for soil.

the material passes from a semisolid to a plastic state. The liquid limit is the moisture content at which the material passes from the plastic liquid state. The plasticity index is the numerical difference between the liquid limit and the plastic limit. It indicates the range of moisture content within which a soil material is in a plastic condition.

Special features affecting highway construction [4]

The soil data listed in the engineering tables are general for a soil, soil type, or soil series. Some soils in the county, however, have features that cannot be fully accounted for in the tables. These features affect highway construction and need further explanation.

Many of the soils in Palo Alto County formed in loamy glacial till. Soils such as Clarion, Nicollet, and Storden soils range from loam to clay loam and are classified A–4 or A–6 and CL. They typically can be compacted to high density with good bearing characteristics. Nicollet soils, however, have a surface layer that is high in organic-matter content and cannot be compacted to high density. Where these soils are in or adjacent to road grades, the material is placed in the upper part of the subgrade in areas that are unstable. Pockets and lenses of sand commonly are interspersed throughout the till and are seasonally water bearing.

Webster and Canisteo soils formed in glacial sediments and glacial till. They have a thick, dark-colored surface layer that is high in organic-matter content to a depth of about 2 feet and cannot be compacted to high density. These soils are classified A–7 and MH, ML, or CL. They have a high moisture content and low density

[4] By CLARE J. SCHROEDER, soils engineer, Iowa State Highway Commission.

test data

Commission, Soils Laboratory, Ames, Iowa]

Mechanical analysis [2]—Continued												
Percentage passing sieve—Continued						Percentage smaller than—				Liquid limit	Plasticity index	AASHTO classification [3]
⅜-in	No. 4 (4.7 mm)	No. 10 (2.0 mm)	No. 40 (0.42 mm)	No. 60 (0.25 mm)	No. 200 (0.074 mm)	0.05 mm	0.02 mm	0.005 mm	0.002 mm			
										Percent		
------	100	99	89	75	60	53	49	36	28	50	24	A–7–6(12)
------	100	99	77	53	38	35	32	23	20	36	18	A–6(3)
95	88	76	34	18	11	9	6	2	2	------	[4] NP	A–1–b(0)
100	99	98	92	85	64	57	44	29	20	43	14	A–7–6(8)
100	96	94	87	80	58	51	38	27	18	34	12	A–6(5)
99	98	94	86	79	55	47	35	25	18	29	12	A–6(5)
------	------	100	87	73	52	35	32	23	18	52	20	A–7–5(8)
100	98	90	71	60	36	31	25	17	14	32	14	A–6(1)
92	84	77	51	38	23	18	14	8	6	25	8	A–2–4(0)
------	------	100	99	97	85	74	53	31	23	43	17	A–7–6(11)
------	------	------	------	100	95	83	53	31	25	40	19	A–6(12)
------	------	------	100	98	43	23	13	6	4	22	1	A–4(2)

[3] Based on AASHTO Designation M 145–49.
[4] Nonplastic.

in places. Because none of this soil material has good subgrade bearing capacity, it should be placed at least 3 feet below the top of the subgrade.

Palms muck, Okoboji, and Blue Earth soils are depressional, are frequently wet, have a high organic-matter content to depths of 3 feet or more, and cannot be compacted to high density. These soils are classified A–7 and OH, OL, or MH to CL, ML, or CH, except Palms muck is classified Pt. This material should be removed and backfilled with more suitable material or placed well below the top of the subgrade. All other soils in the county that are highly organic and that have a topsoil of low density should also be placed well below the top of the subgrade.

Soils that formed in loam on glacial outwash benches, such as Wadena, Cylinder, and Linder soils, are classified A–4 or A–6 and CL. They are underlain by stratified sand and gravel and are classified A–1 or A–2 and SP–SM. Wadena soils generally have a thin surface layer, but sand and gravel in the underlying layers can be used as borrow material and placed in the upper part of the subgrade. Frost heaving may occur, however, unless the level areas are properly drained.

Bottom-land soils formed in alluvium, such as Colo and Wabash soils, have thick surface layers that have a high organic-matter content. These soils may consolidate erratically under an embankment load. They have a low in-place density and a high moisture content. Therefore, if an embankment is to be more than 10 to 15 feet in height, these soils should be carefully analyzed to be sure they are strong enough to support it. Colo soils are classified A–7 and CL, CH, or ML. The clayey Wabash soils are classified A–7 and MH or CH. Spillville soils are also on bottom lands. They are high

in organic-matter content and have a low in-place density. They are classified A–6 or A–4 and CL.

The clayey Waldorf soils formed in lacustrine deposits and are classified A–7 and MH. These soils are on uplands and glacial outwash benches. They are generally in small areas and, in most places, can be bypassed in high construction. If these soils must be crossed by a road grade, excavation to a firm subsoil may be needed, and backfilling with granular material may be desirable.

Dickman soils are sandy and very erodible. Truman soils are silty and are also very erodible. Road embankments in these soils should be protected from wind and water by a ground cover.

Formation and Classification of Soils

This section explains how the factors of soil formation have affected the soils in Palo Alto County. It also explains the system of soil classification currently used and classifies each soil series according to that system.

Factors of Soil Formation

Soil is produced by soil-forming processes acting on materials deposited or accumulated by geologic agencies. The characteristics of the soil at any given point are determined by the physical and mineralogical composition of the parent material, the climate under which the soil material has accumulated and existed since accumulation, the plant and animal life on and in the soil, the relief or lay of the land, and the length of time the forces of soil formation have acted on the soil material.

Climate and plant and animal life, chiefly plants, are active factors of soil formation. They act on the parent material that has accumulated through the weathering of rocks and slowly change it to a neutral body that has genetically related horizons. The effects of climate and plant and animal life are conditioned by relief. The parent material also affects the kind of soil profile that is formed and, in extreme cases, determines it almost entirely. Finally, time is needed for changing the parent material into a soil profile. The time may be long or short, but some time is always required for differentiation of soil horizons. Usually, a long time is required for the development of distinct horizons.

The factors of soil formation are so closely interrelated in their effects on the soil that few generalizations can be made regarding the effect of any one factor unless conditions are specified for the other four. Many of the processes of soil formation are unknown.

Parent material

Soils in Palo Alto County have formed in glacial till, other kinds of glacial drift, glacial outwash, alluvium, organic deposits, wind-deposited sand, and lacustrine sediments. The bedrock beneath these materials has been buried so deeply that it has no influence on the soils.

Palo Alto County has been subject to three major glaciations; the Nebraskan, the Kansan, and the Wisconsin. In Palo Alto County, the Kansan and Nebraskan tills have been removed by subsequent glaciation, or they are buried and not observable.

Palo Alto County lies within the area covered by the Des Moines lobe of the Late Wisconsin Glaciation (*8*). It was formerly believed that the Des Moines lobe was laid down in two substages, the Cary and the Mankato (*8, 9*). According to this view, Palo Alto County would lie within the Mankato substage, the youngest or most recent substage. In more recent investigations, however, evidence indicates that most, if not all of the Des Moines lobe in Iowa is of Cary age (*7*). It has been determined by means of radiocarbon dates that the Cary substage was being deposited about 13,000 years ago.[5] Evidence for the relative youth of the Cary substage is the lack of deep weathering, the presence of unleached calcareous till at a shallow depth, the very poorly organized surface drainage, and the presence of many closed depressions.

The major soils formed in glacial till are the Storden, Clarion, and Nicollet soils. The Salida soils formed in morainal areas where sandy and gravelly knobs are surrounded by glacial till. The Webster soils formed in glacial till and glacial sediments or reworked glacial till overlying glacial till (*19*). The Okoboji, Wacousta, and Rolfe soils formed in reworked glacial till and local alluvium.

Outwash materials deposited by glacial melt water make up an important geologic deposit in Palo Alto County. Extensive deposits of sand and gravel occupy benches along the West Fork Des Moines River and Cylinder Creek. Similar deposits of lesser extent and depth are along other streams and in association with moraines in other parts of the county. Cylinder, Linder, Wadena, Biscay, Hanska, and Estherville soils are important soils formed in these materials.

Soils formed in alluvium are along the streams. Spillville soils, channeled, are composed of recent deposits. The Colo and Wabash soils are older alluvial soils. Some Spillville soils that formed in local alluvium eroded from adjacent slopes are relatively recent in age.

Palms muck formed in accumulated organic matter in old lakebeds or swamps that supported a heavy growth of aquatic plants and vegetation that grew under conditions of excessive wetness. The vegetation partly decomposed and accumulated in fairly thick beds under water. In places deposits of organic matter more than 4 feet deep have been observed in Palo Alto County. Ordinarily glacial drift lies beneath the organic material.

The Dickman and Farrar soils are mainly nearly level to moderately steep and in the uplands. Flagler soils are in areas of outwash and stream benches. Most areas are adjacent to the West Fork Des Moines River. They are fine sands, which were probably deposited by water. Some areas may have been reworked by wind.

The Waldorf soils formed in water-laid lacustrine sediments, which are variable in thickness. In Palo Alto

[5] CARDOSO, J. 1957. Sequence relationships of Clarion, Lester, and Hayden soils catenas. [Unpublished Ph.D. thesis, Iowa State University, Ames, Iowa.]

County, most deposits are about 3½ feet thick and underlain by medium textured to moderately fine textured glacial drift or glacial sediments.

Climate

Climate is a factor that influences the formation of soils in many ways. Rainfall affects the amount of leaching in soils, and it influences the kind of vegetation that grows on soils. Temperature affects the growth of plants, the activity of micro-organisms, and the speed of chemical actions in the soils. Climate is the cause of many of the difference between soils of Palo Alto County and those in other parts of the world. The major differences among soils within the county, however, are attributed to factors other than climate.

Available information indicates that the soils in Palo Alto County have been formed under a midcontinental, subhumid climate for the last 5,000 years (*9*). Between 5,000 and 16,000 years ago the climate was conducive to forest vegetation.

Lane (*4*) assumes that the succession of vegetation in post-Mankato time, from about 11,000 years ago to the present, has been caused by changes in climate. From the succession of vegetation, Lane infers three shifts in climate: namely, warming conditions accompanying a change from coniferous to deciduous trees; gradual desication of climate just prior to the appearance of grasses; and continued grassland climate, including a second dry period. The climatic inferences in recent work by Walker and Brush (*18*) are the same as those of Lane.

The influence of general climate is modified by local conditions in and around the soils. For example, low-lying, poorly drained Webster soils and very poorly drained soils in depressions, such as Okoboji soils, are wetter and colder than most areas around them. South- and west-facing slopes are slightly warmer and less humid than the average climate of nearby areas. These contrasts account for some of the differences in soils within the same general climatic region.

Plant and animal life

Plant and animal life is an important factor in the formation of soils. Plant life is especially significant because differences in the kind of vegetation commonly cause the most marked differences between soils (*6*). As plants grow and die, their remains are added to the soil. Burrowing animals, earthworms, bacteria, protozoa, and fungi help convert these raw plant remains into organic matter. Many kinds of micro-organisms are needed to transform organic remains into stable humus from which plants can obtain nutrients. Humus gives the dark color to surface soil.

Because grasses have many roots and tops that have decayed on or in the soil, soils formed under prairie vegetation have a thick, dark-colored surface layer. In contrast, soils formed under a vegetation of trees have a thinner, lighter colored surface layer because the organic matter, which was derived mainly from leaves, was deposited only on the surface of the soil. Soils that formed under shifting or mixed grass and timber vegetation are intermediate.

Tall prairie grasses were the main native vegetation in Palo Alto County at the time of settlement. Ruhe and Scholtes (*9*) report that for the last 5,000 years the environment in Iowa was conducive to prairie vegetation. From 5,000 to 16,000 years ago, however, the cooler, more moist climate that existed was more favorable to forest vegetation. The effect of the earlier period of forest vegetation is not reflected in the morphology of the Webster, Nicollet, and Clarion soils and other dark-colored soils of Palo Alto County that formed more recently under prairie vegetation. The vegetation in potholes and other depressions was sedges, cattails, rushes, and other similar plants. Trees are presently growing in areas adjacent to streams and lakes in Palo Alto County. They have not existed long enough, however, to significantly alter the morphology of the soils.

Cardoso [see footnote 5, page 90] and McCraken [6] have studied the effects of vegetation on soils similar to those in Palo Alto County.

Topography

Topography is an important cause of differences among soils. Indirectly, it influences soil formation through its effect on drainage, runoff, and erosion. The steeper the slope, the more water runs off the surface and the less soaks into the soil. This results in less leaching of carbonates and less movement of clay from the surface horizon into the B horizon. Soil erosion increases as slopes become steeper. Much of Palo Alto County is nearly level to gently rolling, but many areas are rolling to steep.

Aspect, as well as gradient, has an influence on soil formation. South-facing slopes generally are warmer and drier than north-facing slopes; consequently, they support a different amount of vegetation.

The topography in Palo Alto County is geologically immature, as evidenced by the larger numbers of potholes and other depressions and by the absence of minor upland streams.

Two distinct types of morainal topography are in the county. One is a complex of short, uneven slopes that have many small, indistinct drainage patterns. This kind of topography is prevalent in the western part of the county. The dominant soils on this kind of topography are Storden and Clarion soils. The other type of topography is a series of flat-topped, smooth-sided hills. The major soils on this topography are the Clarion, Nicollet, and Webster soils. Areas adjacent to the major streams are dissected, but have little headward extension.

The Storden, Clarion, and Nicollet soils are examples of soils that formed in the same kind of parent material and under similar vegetation; they differ because of differences in topographic position. The thickness and color of the A horizon and thickness of solum of these soils are related to slope. For example, the thickness and color of the A horizon of the Storden, Clarion, and Nicollet soils are directly related to the topography. The A horizon becomes thicker and darker colored as the slope becomes less steep. The Storden soils typically have the steepest slopes, the Clarion soils have the in-

[6] McCraken, R. 1956. Soil Classification in Polk County, Iowa. [Unpublished Ph.D. thesis, Iowa State University, Ames, Iowa]

termediate slopes, and the Nicollet soils have nearly level slopes. The thickness of the solum also typically increases from Storden to Clarion to Nicollet soils.

In nearly level or depressed areas, the soils are wet and frequently have gray or mottled subsoils because of poor aeration and restricted drainage. Webster soils are an example. In some depressional areas, water collects and is impounded for a period of time. As this water percolates through the soil, clay is removed from the surface and is deposited in the subsoil. This accelerates the development of soils that are very poorly drained and that have a distinct, light-colored subsurface layer and a gray subsoil. Rolfe soils are an example.

Spillville soils, 2 to 5 percent slopes, are on foot slopes and have properties related to the soils upslope from which they receive sediments.

Soils of the Colo, Spillville, and Wabash series are on bottom lands. Although these soils are nearly level, their microrelief affects runoff, depth to water table, and the rate at which they receive new sediments. Colo soils are at low elevations generally some distance from major stream channels. They have a high water table and impound water for short periods of time. Spillville soils are better drained and less clayey than Colo soils.

Time

Geologically, the soils of Palo Alto County are young. The radiocarbon technique for determining the age of carbonaceous material found in till has made it possible to determine the approximate age of soils and Pleistocene deposits in Iowa. Ruhe and Scholtes have studied the ages of soils in Iowa (*7, 9*).

The age of the Cary substage of the Late Wisconsin Glaciation has been determined to be 13,000 years. Thus, all soils formed in it are as young as 13,000 years old or younger. Soils formed in the Cary till include Storden, Clarion, Nicollet, and Webster soils.

In much of Iowa, including Palo Alto County, erosion has beveled and, in places, removed material on side slopes and deposited new sediments downslope (*8, 9*). The surface of nearly level upland summits are older than the side slopes that ascend to the summits. Thus, the side slopes are less than 13,000 years old. Walker, in his studies in Central Iowa in the Wisconsin till areas, found some side slopes to be less than 3,000 years old (*17*). The sediment stripped from side slopes accumulated to form local alluvium. Ruhe found surface layers of soils on summits to be older than surface layers of soils on foot slopes and toe slopes (*8*). Clarion and Storden soils occur on summits and side slopes. Some Spillville soils formed in local alluvium.

The soils on benches that formed in glacial outwash, such as Wadena or Cylinder soils, are less than about 13,000 years old (*8*). Soils that formed in alluvium range in age from recently deposited materials, which make up a part of Spillville loam, channeled, and Spillville soils, to older sediments in which soils such as Colo and Wabash formed. These older sediments are not older than about 13,000 years and are probably much younger.

Some soils in Palo Alto County have clearly defined horizons; some have poorly defined horizons; and some have horizons that are in between. These differences are caused partly by the intensity of the weathering factors and the resistance of soil materials to weathering.

Rolfe soils were exposed to a more intense influence of the five factors of soil formation than were some other soils in the county. As a result they have distinct layers or horizons. Gently sloping Clarion soils have moderately distinct horizons. Webster soils have less distinct horizons because they are in areas where a fluctuating water table modifies the normal effect of time. Storden soils, which formed on steep side slopes, are calcareous throughout, and they show little horizon development. Soils such as Clarion, Storden, and other soils on side slopes are subject to geologic erosion, which continues to expose fresh material. These soils therefore range in age from the time their parent materials were deposited to recent. Soils formed in alluvial deposits adjacent to major streams have little or no profile development.

Man's influence on the soil

Important changes have taken place in soils of Palo Alto County since the county was settled. Breaking the prairie sod and draining some of the many depressions has changed the protective cover.

The most apparent changes are those caused by water erosion. As the land was cultivated, runoff increased and the rate at which water moved into the soil decreased. This resulted in accelerated erosion, which has removed part or all of the surface layer from much of the cultivated sloping land. In some places, a few shallow gullies have formed.

Erosion has changed not only the thickness of the surface layer, but the structure as well. In many severely eroded areas, the plow layer consists partly of the upper part of the subsoil, and in the Storden soils it consists of the upper part of the substratum.

Erosion and cultivation also affect the soil by reducing its organic-matter content, water holding capacity, and fertility. Even in areas not subject to erosion, compaction by heavy machinery reduces the thickness of the surface layer and alters the structure. The granular structure so apparent in virgin grassland breaks down under intensive cropping.

On the other hand, man can and has done much to increase productivity, decrease soil loss, and reclaim areas not suitable for crops or pasture. For example, terraces and erosion control structures and practices have slowed and, in some places, controlled the runoff and soil erosion. Stream straightening and deepening and removing of obstacles have aided in the prevention of flooding and made some areas along streams more suitable for cultivation.

Through the use of commercial fertilizers and lime, the deficiencies in plant nutrients can be corrected so that some soils are more productive than they were in the virgin state.

Erosion is one of the main causes of the reduction of organic-matter content in soils. However, studies indicate that as much as one-third can be lost through causes other than erosion (*12*). Management practices have shown that it is not economically feasible to main-

tain as high a reserve of organic matter as was originally present under native grasses. It is necessary, however, to maintain a safe and economical level for crop production. In soils lowest in organic matter, this is best done by controlling the major cause of loss—erosion by water.

Formation of Horizons

In Palo Alto County morphology is expressed by faint soil horizons in most soils. Storden, Clarion, Webster, and Canisteo soils have faint horizons; Waldorf soils have intermediate horizons; Rolfe soils have prominent horizons. Some soils have a marked difference in texture between the solum and an underlying IIC horizon. Examples are Wadena, Cylinder, Linder, and Biscay soils.

Horizon differentiation is the result of one or more of the following processes: accumulation of organic matter; leaching of calcium carbonate and other bases; formation and translocation of silicate clay minerals; reduction and transfer of iron; and accumulation of calcium carbonates. In most of the soils of the county two or more of these processes have been active in the formation of horizons.

Most soils in Palo Alto County have some accumulation of organic matter in the upper part that forms an A1 horizon. Where the A1 horizon formed in organic deposits, it has a high organic-matter content. Some of the mineral soils that have a high organic-matter content are the Okoboji, Webster, Canisteo, and Colo soils. These soils have a thick A1 horizon. The Salida, Estherville, and Storden soils have a low organic-matter content and have a faint, thin A1 horizon. The Clarion and Wadena soils have a moderate organic-matter content.

Leaching of calcium carbonates and other bases has occurred in many soils in the county. Leaching generally occurs before and during the translocation of silicate clay minerals. Many of the soils in Palo Alto County, however, including the Clarion and Nicollet soils, have been leached of calcium carbonate to a shallow depth, but little clay has been moved downward in their profiles. The Rolfe soils generally are more strongly leached throughout their profiles and have a distinct accumulation of silicate clay in the B horizon.

The translocation of silicate clay minerals has contributed to the prominent horizonation in the Rolfe soils. The B horizon has more clay than the A horizon and, in many places, has dark-colored clay coatings on the faces of peds and along root channels. The eluviated A2 horizon has platy structure, has less clay, and is lighter colored than the B horizon, especially when dry. The leaching of bases and the translocation of clay have been more important processes of horizon differentiation in these soils than the accumulation of organic matter.

Horizonation is faintly expressed in the Harps and Canisteo soils. Carbonates have accumulated in the surface layer and subsoil. The calcium carbonate equivalent of Harps soils is 10 to 40 percent.

Gleying, a result of the reduction and transfer of iron (*10*), is evident in poorly drained and very poorly drained soils. The Okoboji, Webster, Biscay, Wabash, Harps, and Canisteo soils have gleyed Bg horizons, which are gray. Some soils have reddish-brown concretions of iron.

Classification of Soils

Soils are classified so that we can more easily remember their significant characteristics. Classification enables us to assemble knowledge about soils, to see their relationship to one another and to the whole environment, and to develop principles that help us understand their behavior and their response to manipulation. First through classification, and then through use of soil maps, we can apply our knowledge of soils to specific fields and other tracts of land.

Thus in classification, soils are placed in narrow categories that are used in detailed soil surveys so that knowledge about the soils can be organized and used in managing farms, fields, and woodland; in developing rural areas; in engineering work; and in many other ways. Soils are placed in broad classes to facilitate study and comparison in large areas, such as countries and continents.

The system currently used was adopted for general use by the National Cooperative Soil Survey in 1965. The current system is under continual study (*11*). Therefore, readers interested in developments of the current system should search the latest literature available (*14*). In table 8 the soil series of Palo Alto County are placed in some categories of the current system.

The current system of classification has six categories. Beginning with the broadest, these categories are order, suborder, great group, subgroup, family, and series. In this system, the criteria used as a basis for classification are soil properties that are observable and measurable. The properties are chosen, however, so that the soils of similar genesis, or mode of origin, are grouped together. Most of the classes of the current system are briefly defined in the following paragraphs.

ORDER.—Ten soil orders are recognized. They are Entisols, Vertisols, Inceptisols, Aridisols, Mollisols, Spodosols, Alfisols, Ultisols, Oxisols, and Histosols. The properties used to differentiate these soil orders are those that tend to give broad climatic groupings of soils. The two exceptions to this are the Entisols and Histosols, which occur in many different kinds of climate. Table 8 shows that the three soil orders in Palo Alto County are Entisols, Histosols, and Mollisols.

Entisols are light-colored soils that do not have natural genetic horizons or that have only very weakly expressed beginnings of such horizons. These soils do not have traits that reflect soil mixing caused by shrinking and swelling.

Mollisols formed under grass and have a thick, dark-colored surface horizon containing colloids dominated by bivalent cations. The soil material in these soils has not been mixed by shrinking and swelling.

Histosols formed in plant remains. In Palo Alto County these highly organic soils are mainly in large depressions and old lakebeds. Other areas occur as small, round mounds called "fens" (*2*) or as sidehill seeps.

TABLE 8.—*Classification of soil series*

Series	Family	Subgroup	Order
Biscay	Fine-loamy over sandy or sandy-skeletal, mixed, mesic.	Typic Haplaquolls	Mollisols.
Blue Earth	Fine-silty, mixed, calcareous, mesic.	Mollic Fluvaquents	Entisols.
Calco	Fine-silty, mixed, calcareous, mesic.	Cumulic Haplaquolls	Mollisols.
Canisteo	Fine-loamy, mixed, calcareous, mesic.	Typic Haplaquolls	Mollisols.
Clarion	Fine-loamy, mixed, mesic	Typic Hapludolls	Mollisols.
Colo	Fine-silty, mixed, mesic	Cumulic Haplaquolls	Mollisols.
Crippin	Fine-loamy, mixed, mesic	Aquic Hapludolls	Mollisols.
Cylinder	Fine-loamy over sandy or sandy-skeletal, mixed, mesic.	Aquic Hapludolls	Mollisols.
Dickman	Sandy, mixed, mesic	Typic Hapludolls	Mollisols.
Estherville	Coarse-loamy over sandy or sandy-skeletal, mixed, mesic (sandy).	Typic Hapludolls	Mollisols.
Farrar	Coarse-loamy, mixed, mesic	Typic Hapludolls	Mollisols.
Flagler variant	Coarse-loamy, mixed, mesic, calcareous subsoil variant.	Typic Hapludolls	Mollisols.
Hanska	Coarse-loamy, mixed, mesic	Typic Haplaquolls	Mollisols.
Harps	Fine-loamy, mesic	Typic Calciaquolls	Mollisols.
Linder	Coarse-loamy, mixed, mesic	Aquic Hapludolls	Mollisols.
Mayer	Fine-loamy over sandy or sandy-skeletal, mixed, calcareous, mesic.	Typic Haplaquolls	Mollisols.
Nicollet	Fine-loamy, mixed, mesic	Aquic Hapludolls	Mollisols.
Okoboji [1]	Fine, mesic	Cumulic Haplaquolls	Mollisols.
Palms	Loamy, mixed, mesic	Terric Medisaprists	Histosols.
Rolfe [2]	Fine, montmorillonitic, mesic	Typic Argialbolls	Mollisols.
Salida	Sandy-skeletal, mixed, mesic	Entic Hapludolls	Mollisols.
Spillville	Fine-loamy, mixed, mesic	Cumulic Hapludolls	Mollisols.
Storden [3]	Fine-loamy, mixed (calcareous), mesic.	Typic Udorthents	Entisols.
Talcot	Fine-loamy over sandy or sandy-skeletal, mixed, calcareous, mesic.	Typic Haplaquolls	Mollisols.
Truman	Fine-silty, mixed, mesic	Typic Hapludolls	Mollisols.
Wabash	Fine, montmorillonitic, mesic	Vertic Haplaquolls	Mollisols.
Wacousta	Fine-silty, mixed, mesic	Typic Haplaquolls	Mollisols.
Wadena	Fine-loamy over sandy or sandy-skeletal, mixed, mesic (coarse-loamy).	Typic Hapludolls	Mollisols.
Waldorf	Fine, montmorillonitic, mesic	Typic Haplaquolls	Mollisols.
Watseka	Sandy, mixed, mesic	Aquic Hapludolls	Mollisols.
Webster	Fine-loamy, mixed, mesic	Typic Haplaquolls	Mollisols.

[1] Okoboji soils on benches are taxadjuncts to the Okoboji series because they are higher in sand than is allowed in the defined range for the series.
[2] Taxadjuncts to the Rolfe series because they lack an abrupt textural change.
[3] Taxadjuncts to the Storden series because they have a thicker, darker colored surface layer.

SUBORDER.—Each order is divided into suborders, primarily on the basis of the characteristics that seem to produce classes that have the greatest genetic similarity. The suborders narrow the broad climatic range permitted in the orders. The soil properties used to separate suborders are mainly those that reflect either the presence or absence of waterlogging or soil differences resulting from the climate or vegetation.

GREAT GROUP.—Suborders are divided into great groups on the basis of uniformity in the kinds and sequence of major soil horizons and features. The horizons used to make separations are those in which clay, iron, or humus have accumulated or those that contain a pan that interferes with the growth of roots or movement of water. The features used are the self-mulching properties of clays, soil temperature, major differences in chemical composition (mainly calcium, magnesium, sodium, and potassium), and the like. The great group is not shown separately in table 8 because it is the last word in the name of the subgroup.

SUBGROUP.—Great groups are divided into subgroups, one representing the central (typic) segment of the group, and others, called intergrades, that have properties of the group and also one or more properties of another great group, suborder, or order. Subgroups may also be made in those instances where soil properties intergrade outside of the range of any other great group, suborder, or order. The names of subgroups are derived by placing one or more adjectives before the great group.

FAMILY.—Families are established within a subgroup primarily on the basis of properties important to the growth of plants or behavior of soils when used for engineering. Among the properties considered are texture, mineralogy, reaction, soil temperature, permeability, thickness of horizons, and consistence.

SERIES.—The series is a group of soils that have major horizons that, except for texture of surface layer, are similar in important characteristics and in arrangement in the profile.

Environmental Factors Affecting Soil Use

Settlement of Palo Alto County began in 1855 (*5*). The population was 16,170 in 1940, but has gradually declined since that date.

The native vegetation was mainly plants native to the prairie. Sedges and grasses were dominant on the poorly drained and very poorly drained sites. Sedges and marsh grasses grew more extensively on the very poorly drained sites.

Glacial drift and associated glacial outwash, alluvium, organic deposits in depressions, wind deposited sands, and lacustrine sediments are the only geological formations that influence soil use in Palo Alto County.

Large deposits of gravel and sand along the West Fork Des Moines River and in a few glacial outwash areas provide quantities of sand and gravel for commercial use.

Transportation facilities are adequate for existing and any likely new enterprises. Every farm in the county is served by a graded and surfaced road. Most roads are surfaced with gravel. The main farm-to-market roads are surfaced mainly with concrete, and a few with bituminous material. All Federal and State highways are concrete.

Two Federal and State highway systems cross the county. One system goes from east to west and one from north to south. A second north-south system extends about halfway across the county along the eastern border and connects to the east-west system. A short spur extends through the county from the east-west system through the town of Ruthven and another extends to the town of Ayrshire.

A small airport is located at Emmetsburg.

Industry provides markets for farm products within the county. Every town has at least one feed mill and grain elevator. Packing plants provide hog buying stations at most of the towns, and cattle buyers serve the county. Frozen food locker plants are at two or three locations in the county.

Businesses that serve and sell farm equipment and supplies for several different brands are available throughout the county. Seed and farm supply businesses are available throughout the county. Veterinarian services are readily available within the county.

Relief and Drainage

The relief of the western part of the county is dominated by the Altamont end moraine. It is characterized by morainal knobs, hills, and ridges and many land-locked depressions and potholes (fig. 24). Lost Island Lake, Silver Lake, and Virgin Lake are in this part of the survey area. Several large marshes, including Blue Wing, Oppedahl Area, and Fallow Marsh in Lost Island Township and the Rush Lake State Park in Booth Township are also in the area. The relief is strongest and the surface roughest along the western edge of the county near the Palo Alto-Clay County line, where a few morainal hills rise 100 feet or more above the stream valleys.

Washington Hill in Highland Township divides the drainage waters of the county. To the west drainage flows to the Little Sioux River, which empties into the Missouri River. To the east drainage flows to the West Fork Des Moines River, which empties into the Mississippi River.

The topography of the extreme northeastern corner of the county results from the Algona end moraine, and that extending northwest to southeast through the middle part of the county results from the Humboldt end moraine (*8*). Relief in these areas is less rough than in the western part of the county and, in places, more nearly resembles a ground moraine. These areas are undulating to rolling.

In the south-central and north-central parts of the county, and a small area in the east-central part, the topography is that of a ground moraine. It is nearly level to undulating or gently rolling.

Palo Alto County is drained mainly by the West Fork Des Moines River and its tributaries, Cylinder Creek, Jack Creek, Silver Creek, and Pilot Creek. Pick-

***Figure 24.*—Kettles (top photo) and kames (bottom photo) are common in the survey area.**

erel Run drains into Lost Island Lake through the Oppedahl area in Lost Island Township.

The channels of most of these streams, including the West Fork Des Moines River, have been straightened and deepened. In addition, some manmade ditches provide surface drainage and outlets for tile drainage systems.

Climate [7]

Tables 9 and 10 give the temperature, precipitation, and freeze data for the Palo Alto County weather station at Emmetsburg. These data are representative of most of the county, except for the lake areas in the western part and the Des Moines River Valley. Local conditions immediately around the lakes and river may cause different minimum temperatures. On clear, calm nights low areas have minimum temperatures several degrees lower than the surrounding urban and upland areas. Maximum temperatures do not vary as much. In an average year, 20 days have temperatures of 90° F or higher. These temperatures are too high for optimum crop production because water demand is excessive on these days.

The annual precipitation ranges from about 29 inches in the southeastern corner of the county to 28 inches in the northwestern corner. From 1951 to 1960 Emmetsburg averaged 19 days with half an inch or more of rainfall and 53 days with 0.10 inch or more. Heavy rains are important to potential erosion.

Most of the heavy showers occur during the warm half of the year. May, June, and August average 3 days of heavy showers each. About 75 percent of the annual precipitation occurs as showers during the warm season from April through September. The amount of rainfall in individual showers is quite variable over the county, but averages out over a long period of time. June is the wettest month of the year on the average. The dry periods in summer are generally in July. The probability is that an inch or more of rainfall will be received in a 1-week period in June in about 4 years out of 10, and in July and August in about 3 years out of 10. Well developed crops use more than an inch a week during the summer.

Soil moisture is also important for crops. A 5-inch reserve of available soil moisture is considered a critically low level for spring. This survey area has a 25 percent chance that less than 5 inches of water is available for plants in the top 5 feet of soil on April 15 and about a 30 percent chance that more than 9 inches is available.

[7] By ROBERT H. SHAW, professor of climatology, Department of Agronomy, Iowa State University, using data from the National Weather Service, U.S. Department of Commerce.

Water Supply

Palo Alto County has a good supply of underground water. The wells that are properly drilled rarely fail because of seasonal lack of water or periods of drought. Many wells are less than 100 feet deep, but a few are more than 300 feet deep. Shallow wells and sand points are dependable sources of water in some areas where the substratum is gravelly. Water quality is generally good, but a few shallow wells have high nitrate levels.

Two or three wells about 35 to 60 feet deep are in areas where the substratum is gravelly and are dependable sources of irrigation water for about 300 acres. About 17,760 acres have a potential for irrigation. These areas generally border the West Fork Des Moines

TABLE 9.—*Temperature and precipitation*

[Data from Emmetsburg]

Month	Temperature				Precipitation				
	Average daily maximum	Average daily minimum	Average monthly maximum	Average monthly minimum	Average monthly total	One year in 10 will have: Less than—	One year in 10 will have: More than—	Average number of days with snow cover of 1 inch or more	Average depth of snow on days with snow cover
	°F	*°F*	*°F*	*°F*	*Inches*	*Inches*	*Inches*		*Inches*
January	26	7	46	—18	0.6	0.1	2.5	21	6
February	30	11	48	—12	1.2	.2	3.3	17	6
March	38	21	62	0	1.8	.6	4.4	13	7
April	59	35	83	21	2.4	1.0	4.8	1	2
May	71	48	88	32	4.0	1.7	6.3	0	0
June	80	58	93	44	4.8	1.9	9.0	0	0
July	84	62	95	50	2.9	1.3	7.3	0	0
August	83	61	94	47	3.4	1.1	5.7	0	0
September	74	50	90	34	2.5	.4	8.5	([1])	1
October	64	40	84	23	1.5	.4	4.6	([1])	2
November	44	25	66	5	1.3	.1	2.9	3	4
December	32	14	51	—10	.8	.3	2.2	11	5
Year	57	36	98	—20	27.1	18.6	39.6	66	6

[1] Less than one-half day.

TABLE 10.—*Probabilities of last freezing temperatures in spring and first in fall*

[Data from Emmetsburg]

Probability	Dates for given probability and temperature				
	16° F or lower	20° F or lower	24° F or lower	28° F or lower	32° F or lower
Spring:					
1 year in 10 later than	April 5	April 19	April 29	May 7	May 13
2 years in 10 later than	March 30	April 13	April 24	May 2	May 8
5 years in 10 later than	March 20	April 2	April 13	April 22	April 28
Fall:					
1 year in 10 earlier than	October 21	October 19	October 13	October 7	September 20
2 years in 10 earlier than	October 26	October 24	October 19	October 12	September 25
5 years in 10 earlier than	November 6	November 4	October 30	October 23	October 5

River, except for a large outwash area near the town of Cylinder.

A few springs and seepy areas are in the county. A few serve as a source of water for livestock in pasture.

Lost Island, Five Island, Silver, and Virgin Lakes have good water supplies and provide fishing, hunting, boating, swimming, and other recreational activities. Also, the West Fork Des Moines River and numerous gravel pits throughout the county provide similar recreational opportunities. Rush Lake is managed as a marsh and, along with several other marshes in the western part of the county, provides hunting and recreational opportunities.

Camping and picnic areas have been developed, mostly around Lost Island and Five Island Lakes and around one large gravel pit area. There is a potential for further development.

Farming

The Iowa Annual Farm Census for 1970 (*3*) shows that the total land in farms in Palo Alto County was 352,430 acres. Most of this land was in corn, but 18,394 acres was used for pasture. Special crops were harvested on 304 acres, and 72,182 acres was used for lots, roads, buildings, woods, and left as wasteland.

The largest acreage of crops in Palo Alto County is corn. The next largest is soybeans. In 1970, there was 125,913 acres of corn harvested for grain. The average yield was 88.6 bushels per acre. Also, 112,370 acres was used for soybeans, with an average yield of 31.2 bushels per acre.

Palo Alto County farmers produced an average of 61.7 bushels per acre of oats on 12,143 acres. In 1970, there was 11,001 acres of hay of all types in the county. Grain sorghum is beginning to be grown on some farms, especially in fields on the flood plain of the West Fork Des Moines River.

Beef cattle and hogs are the livestock most extensively raised in Palo Alto County. In 1970, there were 43,205 grain-fed cattle sold; 18,410 sows farrowed; and 153,365 hogs marketed. Beef cows totaled 4,420, and there were 1,725 milk cows. There were 2,647 lambs born. There were 105,682 laying hens, 7,615 commercial broilers, and 2,200 turkeys in the county.

In recent years there has been a decline in the number of farms, with an increase in the size of farms. In 1970, there were 4,538 people living on 1,186 farms in Palo Alto County. The farms averaged 297 acres in size. Farm operators owned 37.4 percent of the land, considerably below the State of Iowa average of 52.8 percent. Tenants operated 62.6 percent of the land as compared to the State average of 47.2 percent.

Many farms in the county derive a large part of their income from livestock sales, especially hogs and beef cattle that have been raised on the farms. Many farms maintain beef-cow herds, and in recent years beef-cow numbers have been increasing. Some farms, scattered throughout the county, are of the cash grain type and derive most of their income from the sale of corn and soybeans. On some farms, dairying is a major enterprise. The number of dairy farms has been decreasing in recent years. Size of remaining herds, however, is increasing. Some poultry and a few turkeys are also raised. There has been a recent tend to fewer, but larger, poultry operations, mainly to laying units. Commercial broiler and turkey production has been declining in recent years.

Sheep are raised on a few farms, and numbers have remained about steady.

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Glossary

Acidity. See Reaction, soil.

Bench. A high, shelflike position.

Bottom land. The normal flood plain of a stream.

Calcareous soil. A soil containing enough calcium carbonate (often with magnesium carbonate) to effervesce (fizz) visibly when treated with cold, dilute hydrochloric acid.

Clay. As a soil separate, the mineral soil particles less than 0.002 millimeter in diameter. As a soil textural class, soil material that is 40 percent or more clay, less than 45 percent sand, and less than 40 percent silt.

Consistence, soil. The feel of the soil and the ease with which a lump can be crushed by the fingers. Terms commonly used to describe consistence are—

Loose.—Noncoherent when dry or moist; does not hold together in a mass.

Friable.—When moist, crushes easily under gentle pressure between thumb and forefinger and can be pressed together into a lump.

Firm.—When moist, crushes under moderate pressure between thumb and forefinger, but resistance is distinctly noticeable.

Plastic.—When wet, readily deformed by moderate pressure but can be pressed into a lump; will form a "wire" when rolled between thumb and forefinger.

Sticky.—When wet, adheres to other material, and tends to stretch somewhat and pull apart, rather than to pull free from other material.

Hard.—When dry, moderately resistant to pressure; can be broken with difficulty between thumb and forefinger.

Soft.—When dry, breaks into powder or individual grains under very light pressure.

Cemented.—Hard and brittle; little affected by moistening.

Contour tillage. Cultivation that follows the contour of the land, generally at right angles to the slope or parallel to terrace grade.

Drift (geology). Material of any sort deposited by geologic processes in one place after having been removed from another. Drift includes material deposited by glaciers and by the streams and lakes associated with glaciers.

Erosion. The wearing away of the land surface by wind (sandblast), running water, and other geological agents.

Flood plain. Nearly level land, consisting of stream sediments, that borders a stream and is subject to flooding unless protected artificially.

Glacial drift. Rock material transported by glacial ice and then deposited; includes the assorted and unassorted materials deposited by streams flowing from glaciers.

Glacial outwash. Cross-bedded gravel, sand, and silt deposited by melt water as it flowed from glacial ice. Referred to in this survey as "outwash areas" and "glacial outwash benches."

Glacial till. Unassorted, nonstratified glacial drift consisting of clay, silt, sand, and boulders transported and deposited by glacial ice.

Gley. A soil horizon in which waterlogging and lack of oxygen have caused the material to be neutral gray in color.

Horizon, soil. A layer of soil, approximately parallel to the surface, that has distinct characteristics produced by soil-forming processes. These are the major horizons:

O horizon.—The layer of organic matter on the surface of a mineral soil. This layer consists of decaying plant residues.

A horizon.—The mineral horizon at the surface or just below an O horizon. This horizon is the one in which living organisms are most active and therefore is marked by the accumulation of humus. The horizon may have lost one or more of soluble salts, clay, and sesquioxides (iron and aluminum oxides).

B horizon.—The mineral horizon below an A horizon. The B horizon is in part a layer of change from the overlying A to the underlying C horizon. The B horizon also has distinctive characteristics caused (1) by accumulation of clay, sesquioxides, humus, or some combination of these; (2) by prismatic or blocky structure; (3) by redder or stronger colors than the A horizon; or (4) by some combination of these. Combined A and B horizons are usually called the solum, or true soil. If a soil lacks a B horizon, the A horizon alone is the solum.

C horizon.—The weathered rock material immediately beneath the solum. In most soils this material is presumed to be like that from which the overlying horizons were formed. If the material is known to be different from that in the solum, a Roman numeral precedes the letter C.

R layer.—Consolidated rock beneath the soil. The rock usually underlies a C horizon but may be immediately beneath an A or B horizon.

Leaching. The removal of soluble materials from the soils or other materials by percolating water.

Mottling, soil. Irregularly marked with spots of different colors that vary in number and size. Mottling in soils usually indicates poor aeration and lack of drainage. Descriptive terms are as follows: abundance—*few, common,* and *many;* size—*fine, medium,* and *coarse;* and contrast—*faint, distinct,* and *prominent.* The size measurements are these: *fine,* less than 5 millimeters (about 0.2 inch) in diameter along the greatest dimension; *medium,* ranging from 5 to 15 millimeters (about 0.2 to 0.6 inch) in diameter along the greatest dimension; and *coarse,* more than 15 millimeters (about 0.6 inch) in diameter along the greatest dimension.

Parent material. Disintegrated and partly weathered rock from which soil has formed.

Ped. An individual natural soil aggregate, such as a crumb, a prism, or a block, in contrast to a clod.

Percolation. The downward movement of water through soil.

Profile, soil. A vertical section of the soil through all its horizons and extending into the parent material.

Reaction, soil. The degree of acidity or alkalinity of a soil, expressed in pH values. A soil that tests to pH 7.0 is precisely neutral in reaction because it is neither acid nor alkaline. An acid, or "sour," soil is one that gives an acid reaction; an alkaline soil is one that is alkaline in reaciton. In words, the degrees of acidity or alkalinity are expressed thus:

Extremely acid	Below 4.5
Very strongly acid	4.5 to 5.0
Strongly acid	5.1 to 5.5
Medium acid	5.6 to 6.0
Slightly acid	6.1 to 6.5
Neutral	6.6 to 7.3
Mildly alkaline	7.4 to 7.8
Moderately alkaline	7.9 to 8.4
Strongly alkaline	8.5 to 9.0
Very strongly alkaline	9.1 and higher

Relief. The elevations or inequalities of a land surface, considered collectively.

Sand. Individual rock or mineral fragments in a soil that range in diameter from 0.05 to 2.0 millimeters. Most sand grains consist of quartz, but they may be of any mineral composition. The textural class name of any soil that contains 85 percent or more sand and not more than 10 percent clay.

Series, soil. A group of soils developed from a particular type of parent material and having genetic horizons that, except for texture of the surface layer, are similar in differentiating characteristics and in arrangement in the profile.

Silt. Individual mineral particles in a soil that range in diameter from the upper limit of clay (0.002 millimeter) to the lower limit of very fine sand (0.05 millimeter). Soil of the silt textural class is 80 percent or more silt and less than 12 percent clay.

Soil. A natural, three-dimensional body on the earth's surface that supports plants and that has properties resulting from the integrated effect of climate and living matter acting on earthy parent material, as conditioned by relief over periods of time.

Solum. The upper part of a soil profile, above the parent material, in which the processes of soil formation are active. The solum in mature soil includes the A and B horizons. Generally, the characteristics of the material in these horizons are unlike those of the underlying material. The living roots and other plant and animal life characteristic of the soil are largely confined to the solum.

Structure, soil. The arrangement of primary soil particles into compound particles or clusters that are separated from adjoining aggregates and have properties unlike those of an equal mass of unaggregated primary soil particles. The principal forms of soil structure are—*platy* (laminated), *prismatic* (vertical axis of aggregates longer than horizontal), *columnar* (prisms with rounded tops), *blocky* (angular or subangular), and *granular*. *Structureless* soils are either *single grained* (each grain by itself, as in dune sand) or *massive* (the particles) adhering together without any regular cleavage, as in many claypans and hardpans.

Subsoil. Technically, the B horizon; roughly, the part of the solum below plow depth.

Substratum. Technically, the part of the soil below the solum.

Surface soil. The soil ordinarily moved in tillage, or its equivalent in uncultivated soil, about 5 to 8 inches in thickness. The plowed layer.

Terrace. An embankment, or ridge, constructed across sloping soils on the contour or at a slight angle to the contour. The terrace intercepts surface runoff so that it may soak into the soil or flow slowly to a prepared outlet without harm. Terraces in fields are generally built so they can be farmed. Terraces intended mainly for drainage have a deep channel that is maintained in permanent sod.

Terrace. (geological). An old alluvial plain, ordinarily flat or undulating, bordering a river, lake, or the sea. Stream terraces are frequently called second bottoms, as contrasted to flood plains, and are seldom subject to overflow. Marine terraces were deposited by the sea and are generally wide.

Texture, soil. The relative proportions of sand, silt, and clay particles in a mass of soil. The basic textural classes, in order of increasing proportion of fine particles, are *sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay,* and *clay*. The sand, loamy sand, and sandy loam classes may be further divided by specifying "coarse," "fine," or "very fine."

Tilth, soil. The condition of the soil in relation to the growth of plants, especially soil structure. Good tilth refers to the friable state and is associated with high noncapillary porosity and stable, granular structure. A soil in poor tilth is nonfriable, hard, nonaggregated, and difficult to till.

Water table. The highest part of the soil or underlying rock material that is wholly saturated with water. In some places an upper, or perched, water table may be separated from a lower one by a dry zone.

GUIDE TO MAPPING UNITS

Map symbol	Mapping unit	Page	Capability unit Symbol	Capability unit Page	Environmental planting group Number
6	Okoboji silty clay loam, 0 to 1 percent slopes	37	IIIw-1	59	2
T6	Okoboji silty clay loam, benches, 0 to 1 percent slopes	38	IIIw-1	59	2
34	Estherville sandy loam, 0 to 2 percent slopes	28	IIIs-1	60	4
34B	Estherville sandy loam, 2 to 5 percent slopes	28	IIIe-3	59	4
34C2	Estherville sandy loam, 5 to 9 percent slopes, moderately eroded	28	IIIe-4	59	4
55	Nicollet loam, 1 to 3 percent slopes	35	I-1	56	1
62C	Storden loam, 5 to 9 percent slopes	45	IIIe-1	58	3
62D	Storden loam, 9 to 14 percent slopes	45	IIIe-2	58	3
62E	Storden loam, 14 to 18 percent slopes	45	IVe-1	60	3
62F	Storden loam, 18 to 25 percent slopes	45	VIe-1	61	3
72	Estherville loam, 0 to 2 percent slopes	28	IIIs-1	60	4
72B	Estherville loam, 2 to 5 percent slopes	28	IIIe-3	59	4
73C	Salida gravelly sandy loam, 4 to 12 percent slopes	42	IIIe-4	59	4
90	Okoboji mucky silt loam, 0 to 1 percent slopes	38	IIIw-2	59	2
95	Harps loam, 0 to 2 percent slopes	32	IIw-3	57	2
107	Webster silty clay loam, 0 to 2 percent slopes	54	IIw-1	56	2
133	Colo silty clay loam, 0 to 2 percent slopes	23	IIw-2	57	2
133B	Colo silty clay loam, 2 to 4 percent slopes	23	IIw-1	56	2
138B	Clarion loam, 2 to 5 percent slopes	19	IIe-1	56	1
138C	Clarion loam, 5 to 9 percent slopes	19	IIIe-1	58	1
138C2	Clarion loam, 5 to 9 percent slopes, moderately eroded	20	IIIe-1	58	1
138D2	Clarion loam, 9 to 14 percent slopes, moderately eroded	20	IIIe-2	58	1
141	Watseka loamy fine sand, 0 to 2 percent slopes	53	IIIs-1	60	4
150	Hanska loam, moderately deep, 0 to 2 percent slopes	31	IIw-4	57	2
172	Wabash silty clay, 0 to 2 percent slopes	49	IIIw-3	60	2
181B	Clarion-Estherville complex, 2 to 5 percent slopes	21	IIe-1	56	4
181C2	Clarion-Estherville complex, 5 to 9 percent slopes, moderately eroded	22	IIIe-4	59	4
203	Cylinder loam, deep, 0 to 2 percent slopes	26	I-2	56	1
221	Palms muck, 0 to 1 percent slopes	39	IIIw-2	59	2
224	Linder loam, 0 to 2 percent slopes	33	IIs-1	58	4
253C	Farrar fine sandy loam, 5 to 9 percent slopes	29	IIIe-4	59	1
259	Biscay clay loam, deep, 0 to 2 percent slopes	14	IIw-5	58	2
274	Rolfe silt loam, 0 to 1 percent slopes	40	IIIw-1	59	2
308	Wadena loam, deep, 0 to 3 percent slopes	51	I-2	56	1
324	Dickman fine sandy loam, loamy substratum, 0 to 2 percent slopes	26	IIIs-1	60	4
324B	Dickman fine sandy loam, loamy substratum, 2 to 5 percent slopes	27	IIIe-3	59	4
339	Truman silt loam, 0 to 2 percent slopes	48	I-1	56	1
339B	Truman silt loam, 2 to 6 percent slopes	48	IIe-1	56	1
354	Marsh	33	VIIw-1	61	2
390	Waldorf silty clay loam, 0 to 2 percent slopes	52	IIw-1	56	2
485	Spillville loam, 0 to 2 percent slopes	43	IIw-2	57	1
485B	Spillville loam, 2 to 5 percent slopes	43	IIe-1	56	1
C485	Spillville loam, channeled, 0 to 2 percent slopes	43	Vw-1	61	1
506	Wacousta silty clay loam, 0 to 1 percent slopes	50	IIIw-1	59	2
507	Canisteo silty clay loam, 0 to 2 percent slopes	17	IIw-1	56	2
511	Blue Earth mucky silt loam, 0 to 1 percent slopes	15	IIIw-2	59	2
559	Talcot clay loam, deep, 0 to 2 percent slopes	47	IIw-5	58	2
585B	Colo-Spillville complex, 2 to 5 percent slopes	23	IIw-2	57	2
638B	Clarion-Storden loams, 2 to 5 percent slopes	22	IIe-1	56	3
639C	Storden-Salida complex, 5 to 9 percent slopes	46	IIIe-4	59	4
639D	Storden-Salida complex, 9 to 14 percent slopes	46	IIIe-4	59	4
639E	Storden-Salida complex, 14 to 18 percent slopes	46	IVe-2	61	4
655	Crippin loam, 0 to 3 percent slopes	25	I-1	56	3
658	Mayer loam, moderately deep, 0 to 2 percent slopes	34	IIw-5	58	3
733	Calco silty clay loam, 0 to 2 percent slopes	16	IIw-2	57	2
823	Flagler sandy loam, calcareous subsoil variant, 0 to 2 percent slopes	30	IIIs-1	60	4

Map symbol	Mapping unit	Page	Capability unit Symbol	Capability unit Page	Environmental planting group Number
823B	Flagler sandy loam, calcareous subsoil variant, 2 to 5 percent slopes	30	IIIe-3	59	4
895	Mayer loam, sandy loam subsoil, 0 to 2 percent slopes	34	IIw-4	57	3

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U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

IOWA AGRICULTURAL AND HOME ECONOMICS EXPERIMENT STATION
COOPERATIVE EXTENSION SERVICE, IOWA STATE UNIVERSITY
DEPARTMENT OF SOIL CONSERVATION, STATE OF IOWA

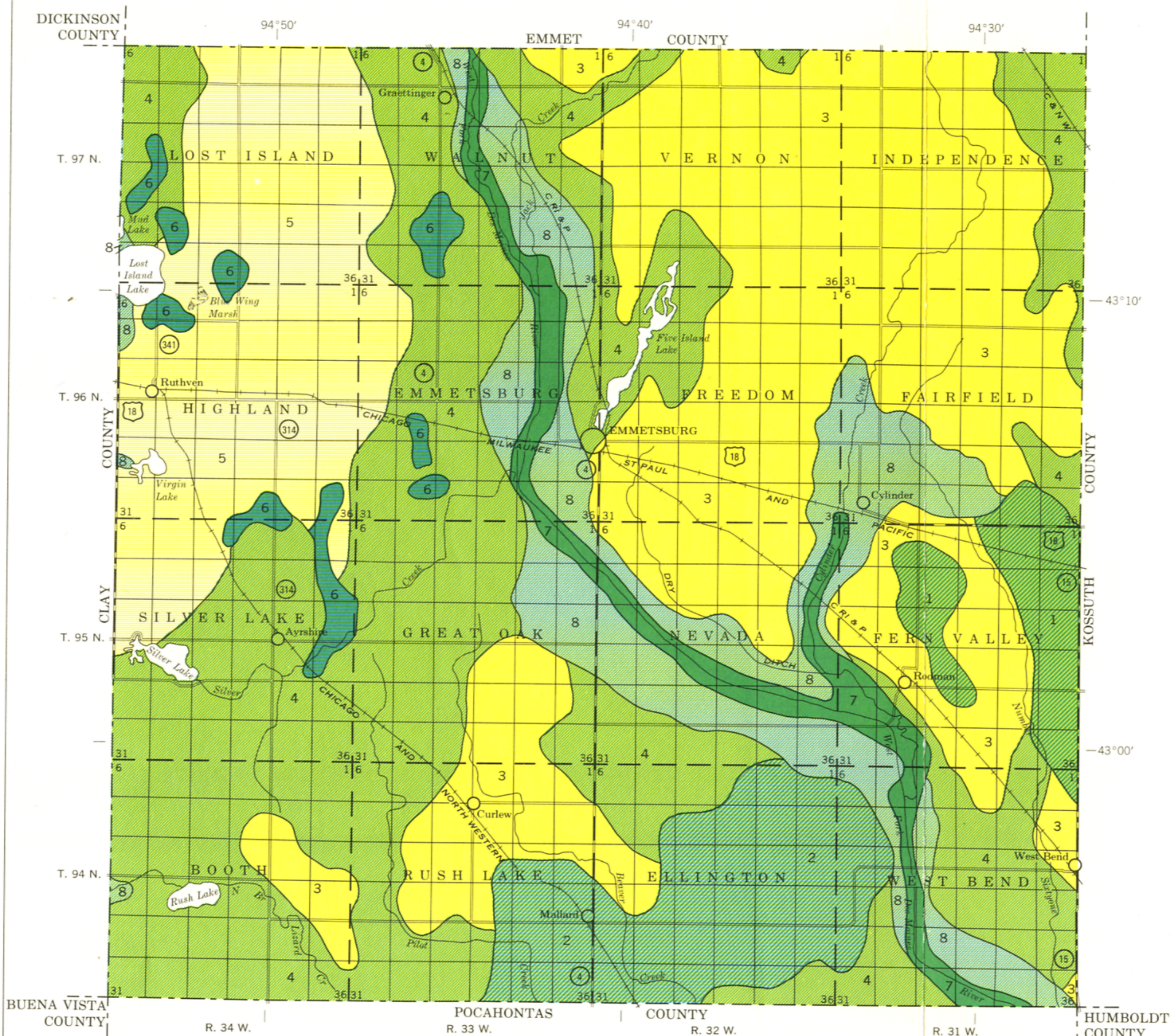
GENERAL SOIL MAP

PALO ALTO COUNTY, IOWA

Scale 1:190,080

1 0 1 2 3 4 Miles

N



SOIL ASSOCIATIONS

1 Canisteo-Nicollet-Webster association: Nearly level, medium textured and moderately fine textured, poorly drained and somewhat poorly drained soils on uplands

2 Clarion-Canisteo-Nicollet association: Gently sloping and nearly level, medium textured and moderately fine textured, well drained to poorly drained soils on uplands

3 Clarion-Nicollet-Canisteo association: Moderately sloping to nearly level, medium textured and moderately fine textured, well drained to poorly drained soils on uplands

4 Clarion-Nicollet association: Strongly sloping to nearly level, medium textured, well drained to somewhat poorly drained soils on uplands

5 Clarion-Storden-Nicollet-Canisteo association: Moderately sloping to moderately steep, medium textured and moderately fine textured, somewhat excessively drained to poorly drained soils on uplands

6 Storden-Clarion-Salida association: Nearly level to moderately steep, medium textured and moderately coarse textured, well drained to excessively drained soils on uplands and outwash plains

7 Spillville-Colo association: Nearly level, moderately well drained to poorly drained, medium textured and moderately fine textured soils on bottom land

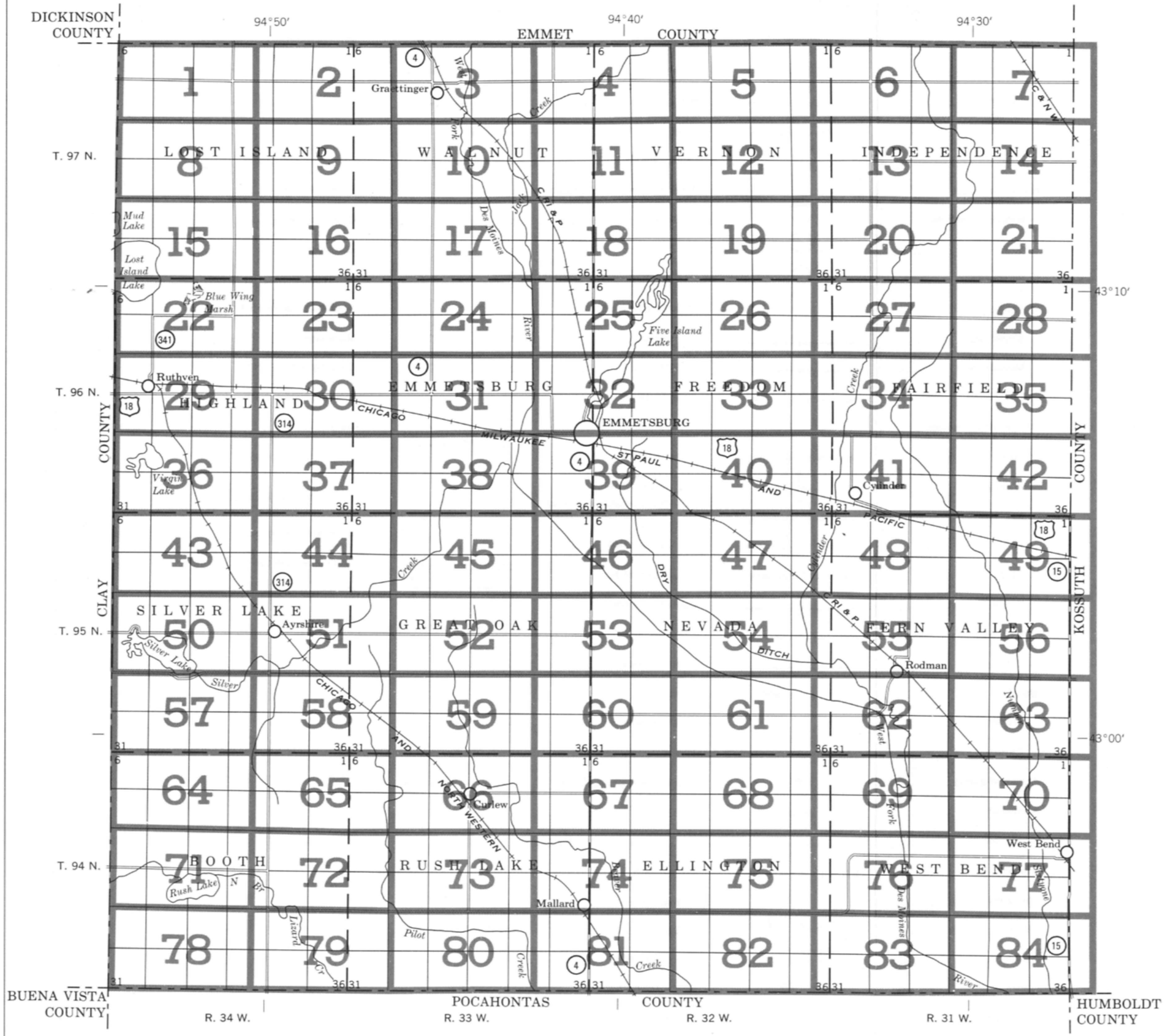
8 Estherville-Hanska-Linder association: Nearly level, excessively drained to poorly drained, moderately coarse textured and medium textured soils on stream benches and outwash plains

Compiled 1975

Each area outlined on this map consists of more than one kind of soil. The map is thus meant for general planning rather than a basis for decisions on the use of specific tracts.

SECTIONALIZED TOWNSHIP

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36



INDEX TO MAP SHEETS

PALO ALTO COUNTY, IOWA

Scale 1:190,080

1 0 1 2 3 4 Miles

N

SECTIONALIZED TOWNSHIP

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

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CONVENTIONAL SIGNS

WORKS AND STRUCTURES

Highways and roads
- Divided
- Good motor
- Poor motor
- Trail

Highway markers
- National Interstate
- U. S.
- State or county

Railroads
- Single track
- Multiple track
- Abandoned

Bridges and crossings
- Road
- Flood gate
- Railroad
- Ferry — FY
- Ford — FORD
- Grade
- R. R. over
- R. R. under

Buildings
- School
- Church

Mine and quarry

Gravel pit — G.P.

Power line

Pipeline

Cemetery

Dams

Levee

Tanks

Well, oil or gas

Forest fire or lookout station

Windmill

Located object

BOUNDARIES

- National or state
- County
- Minor civil division
- Large park
- Land grant
- Small park, cemetery, airport
- Land survey division corners

DRAINAGE

Streams, double-line
- Perennial
- Intermittent

Streams, single-line
- Perennial
- Intermittent
  - Crossable with tillage implements
  - Not crossable with tillage implements, stabilized grade
  - Unclassified

Canals and ditches

Lakes and ponds
- Perennial — water, w
- Intermittent — int

Spring

Marsh or swamp

Wet spot

Drainage end or alluvial fan

RELIEF

Escarpments
- Bedrock
- Other

Short steep slope

Prominent peak

Depressions (Large, Small)
- Crossable with tillage implements
- Not crossable with tillage implements
- Contains water most of the time

SOIL SURVEY DATA

- Soil boundary and symbol — 308C
- Gravel
- Stoniness
  - Stony
  - Very stony
- Rock outcrops
- Chert fragments
- Clay spot
- Sand spot
- Gumbo or scabby spot
- Made land — M.L.
- Severely eroded spot
- Blowout, wind erosion
- Gully
- Small area clarion soil (small knoll)
- Conical mounds of peat or muck
- Small area okoboji soil
- Small area rolfe soil
- Calcareous spot
- Sewage lagoon — S.L.

SOIL LEGEND

Symbols consist of numbers or a combination of numbers and letters, for example 72B, 259, 639D2. The 1, 2, or 3 digit number designates the kind of soil or land type. A capital letter B, C, D, E, or F following a number indicates the class of slope. Symbols without a slope letter are those for units that are nearly level. A final number 2 following a letter in a symbol indicates that the soil is moderately eroded. The capital C or T used as a prefix indicates a channeled phase or a bench phase, respectively.

SYMBOL	NAME
6	Okoboji silty clay loam, 0 to 1 percent slopes
T6	Okoboji silty clay loam, benches, 0 to 1 percent slopes
34	Estherville sandy loam, 0 to 2 percent slopes
34B	Estherville sandy loam, 2 to 5 percent slopes
34C2	Estherville sandy loam, 5 to 9 percent slopes, moderately eroded
55	Nicollet loam, 1 to 3 percent slopes
62C	Storden loam, 5 to 9 percent slopes
62D	Storden loam, 9 to 14 percent slopes
62E	Storden loam, 14 to 18 percent slopes
62F	Storden loam, 18 to 25 percent slopes
72	Estherville loam, 0 to 2 percent slopes
72B	Estherville loam, 2 to 5 percent slopes
73C	Salida gravelly sandy loam, 4 to 12 percent slopes
90	Okoboji mucky silt loam, 0 to 1 percent slopes
95	Harps loam, 0 to 2 percent slopes
107	Webster silty clay loam, 0 to 2 percent slopes
133	Colo silty clay loam, 0 to 2 percent slopes
133B	Colo silty clay loam, 2 to 4 percent slopes
138B	Clarion loam, 2 to 5 percent slopes
138C	Clarion loam, 5 to 9 percent slopes
138C2	Clarion loam, 5 to 9 percent slopes, moderately eroded
138D2	Clarion loam, 9 to 14 percent slopes, moderately eroded
141	Watseka loamy fine sand, 0 to 2 percent slopes
150	Hanska loam, moderately deep, 0 to 2 percent slopes
172	Wabash silty clay, 0 to 2 percent slopes
181B	Clarion-Estherville complex, 2 to 5 percent slopes
181C2	Clarion-Estherville complex, 5 to 9 percent slopes, moderately eroded
203	Cylinder loam, deep, 0 to 2 percent slopes
221	Palms muck, 0 to 1 percent slopes
224	Linder loam, 0 to 2 percent slopes
253C	Farrar fine sandy loam, 5 to 9 percent slopes
259	Biscay clay loam, deep, 0 to 2 percent slopes
274	Rolfe silt loam, 0 to 1 percent slopes
308	Wadena loam, deep, 0 to 3 percent slopes
324	Dickman fine sandy loam, loamy substratum, 0 to 2 percent slopes
324B	Dickman fine sandy loam, loamy substratum, 2 to 5 percent slopes
339	Truman silt loam, 0 to 2 percent slopes
339B	Truman silt loam, 2 to 6 percent slopes
354	Marsh
390	Waldorf silty clay loam, 0 to 2 percent slopes
485	Spillville loam, 0 to 2 percent slopes
485B	Spillville loam, 2 to 5 percent slopes
C485	Spillville loam, channeled, 0 to 2 percent slopes
506	Wacousta silty clay loam, 0 to 1 percent slopes
507	Canisteo silty clay loam, 0 to 2 percent slopes
511	Blue Earth mucky silt loam, 0 to 1 percent slopes
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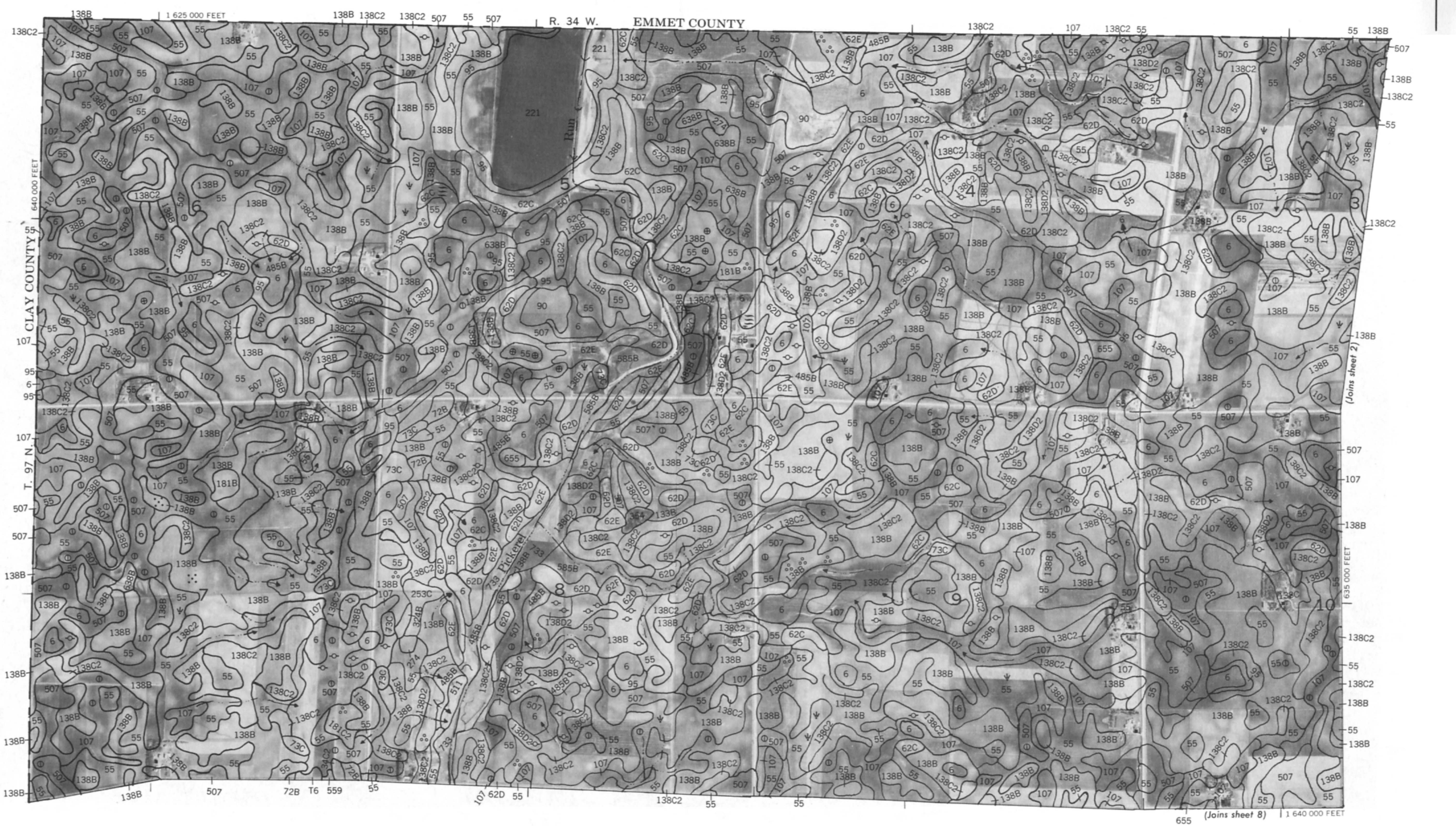
638B	Clarion-Storden loams, 2 to 5 percent slopes
639C	Storden-Salida complex, 5 to 9 percent slopes
639D	Storden-Salida complex, 9 to 14 percent slopes
639E	Storden-Salida complex, 14 to 18 percent slopes
655	Crippin loam, 0 to 3 percent slopes
658	Mayer loam, moderately deep, 0 to 2 percent slopes
733	Calco silty clay loam, 0 to 2 percent slopes
823	Flagler sandy loam, calcareous subsoil variant, 0 to 2 percent slopes
823B	Flagler sandy loam, calcareous subsoil variant, 2 to 5 percent slopes
895	Mayer loam, sandy loam subsoil, 0 to 2 percent slopes

PALO ALTO COUNTY, IOWA — SHEET NUMBER 1



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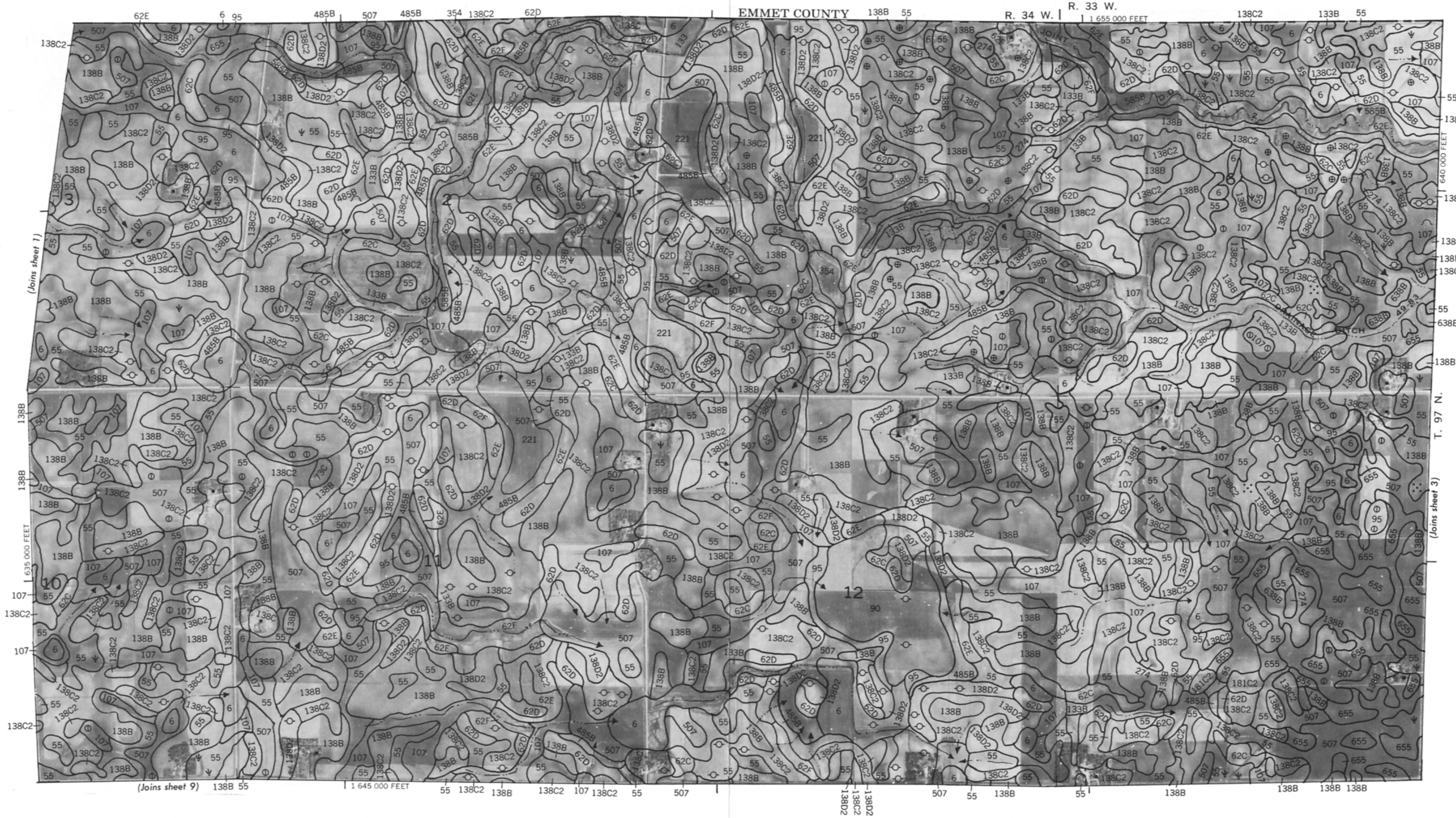
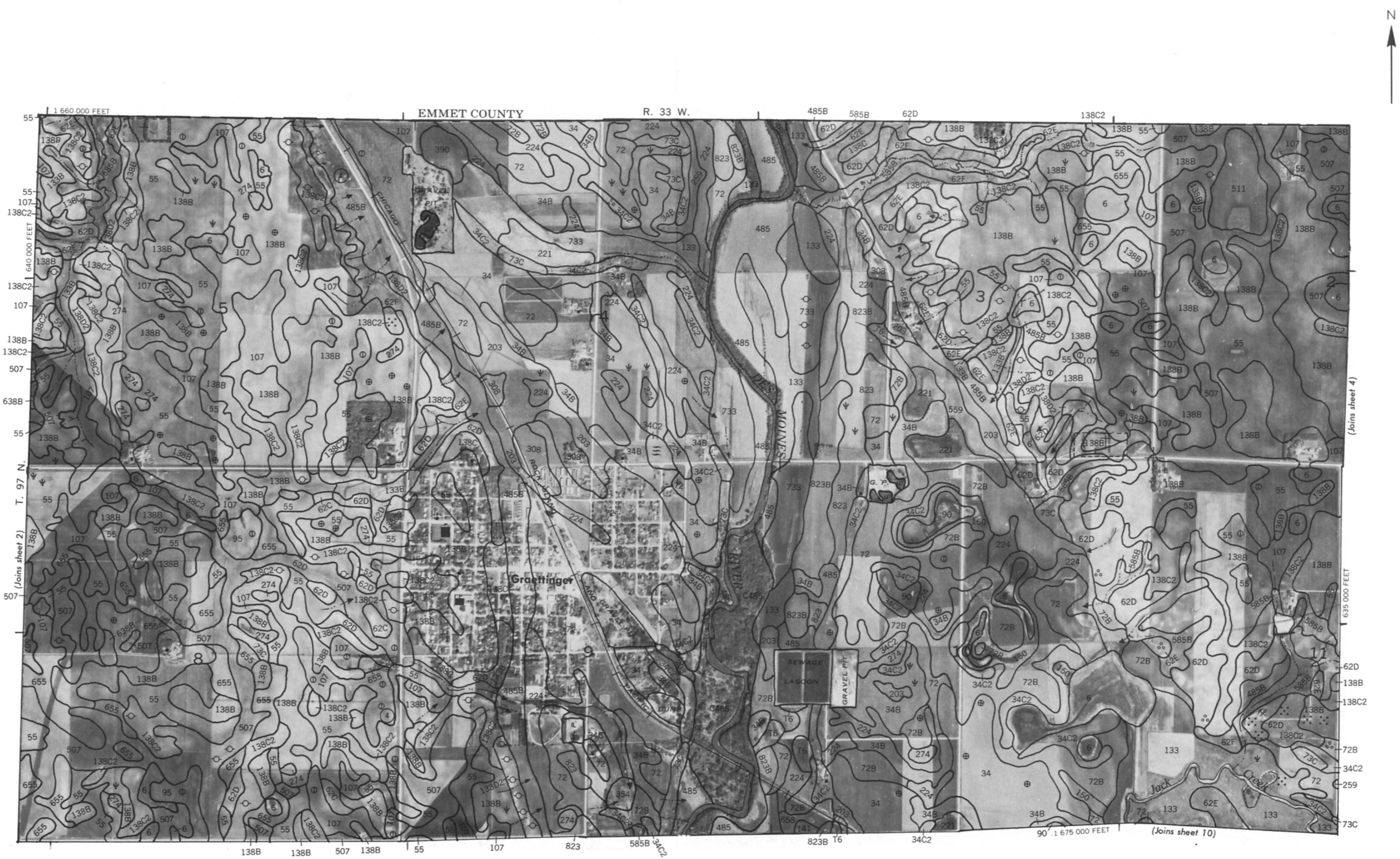

EMMET COUNTY
R. 34 W.
R. 33 W.
1 655 000 FEET
640 000 FEET
T. 97 N.
(Joins sheet 3)
(Joins sheet 9)
1 645 000 FEET
635 000 FEET
(Joins sheet 1)
JOINT
DRAINAGE DITCH
49-83

N


EMMET COUNTY
R. 33 W.
T. 97 N.
1 660 000 FEET
1 675 000 FEET
640 000 FEET
635 000 FEET
(Joins sheet 2)
(Joins sheet 4)
(Joins sheet 10)
Graettinger
DES MOINES RIVER
CHICAGO
ROCK ISLAND AND PACIFIC
GRAVEL PIT
SEWAGE LAGOON
DUMP
Jack Creek

PALO ALTO COUNTY, IOWA — SHEET NUMBER 4

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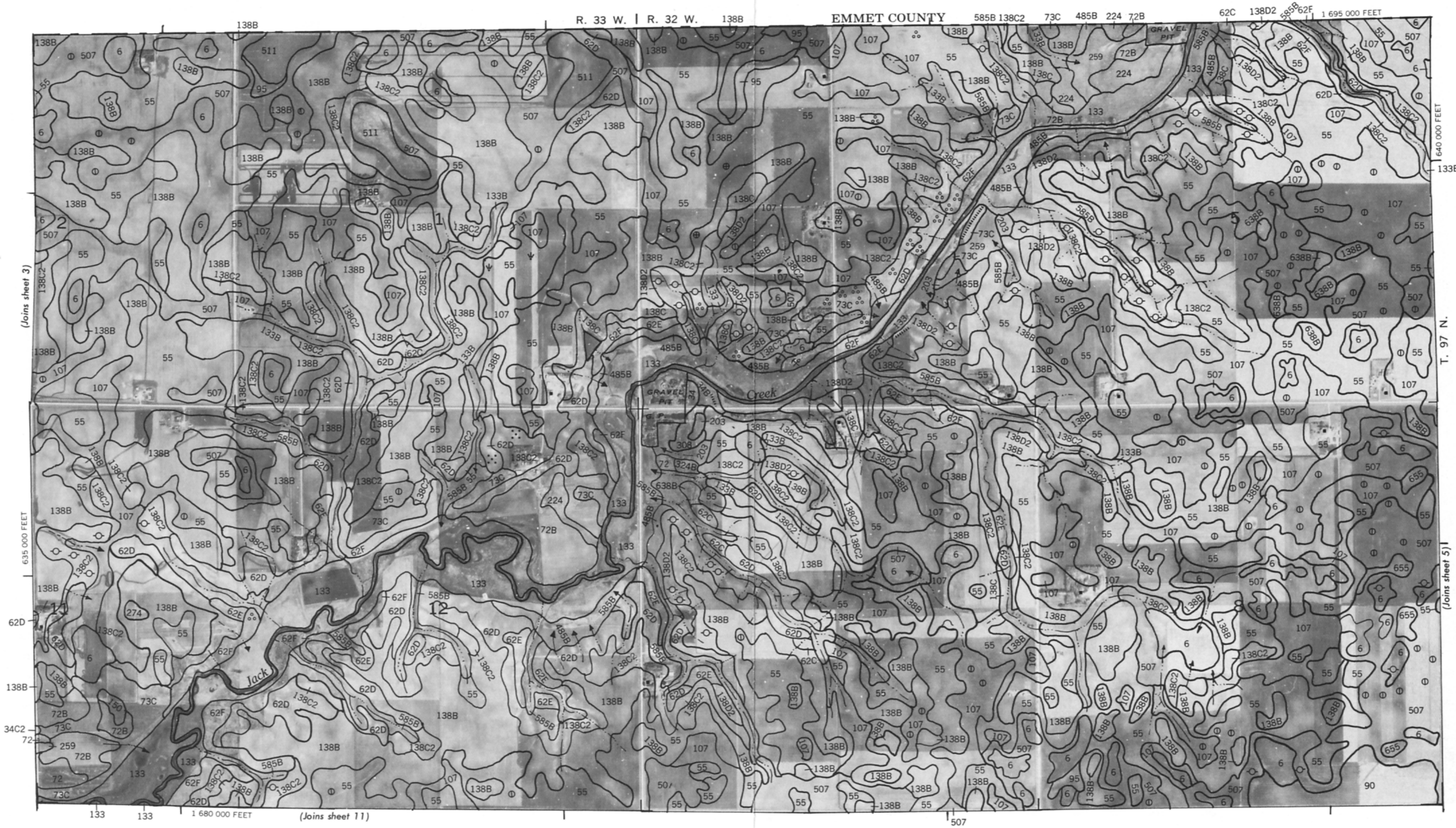

PALO ALTO COUNTY, IOWA — SHEET NUMBER 5

5

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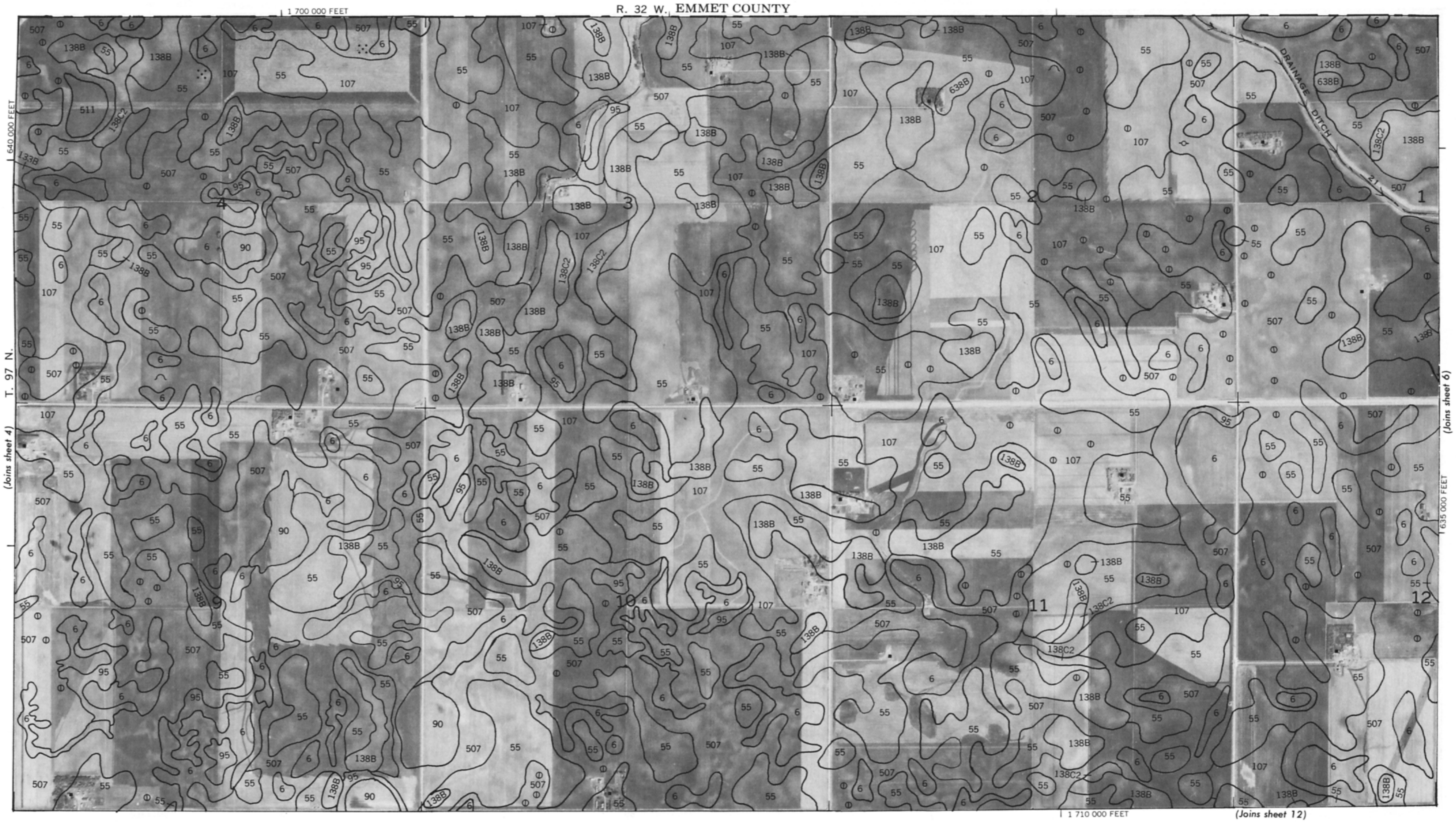
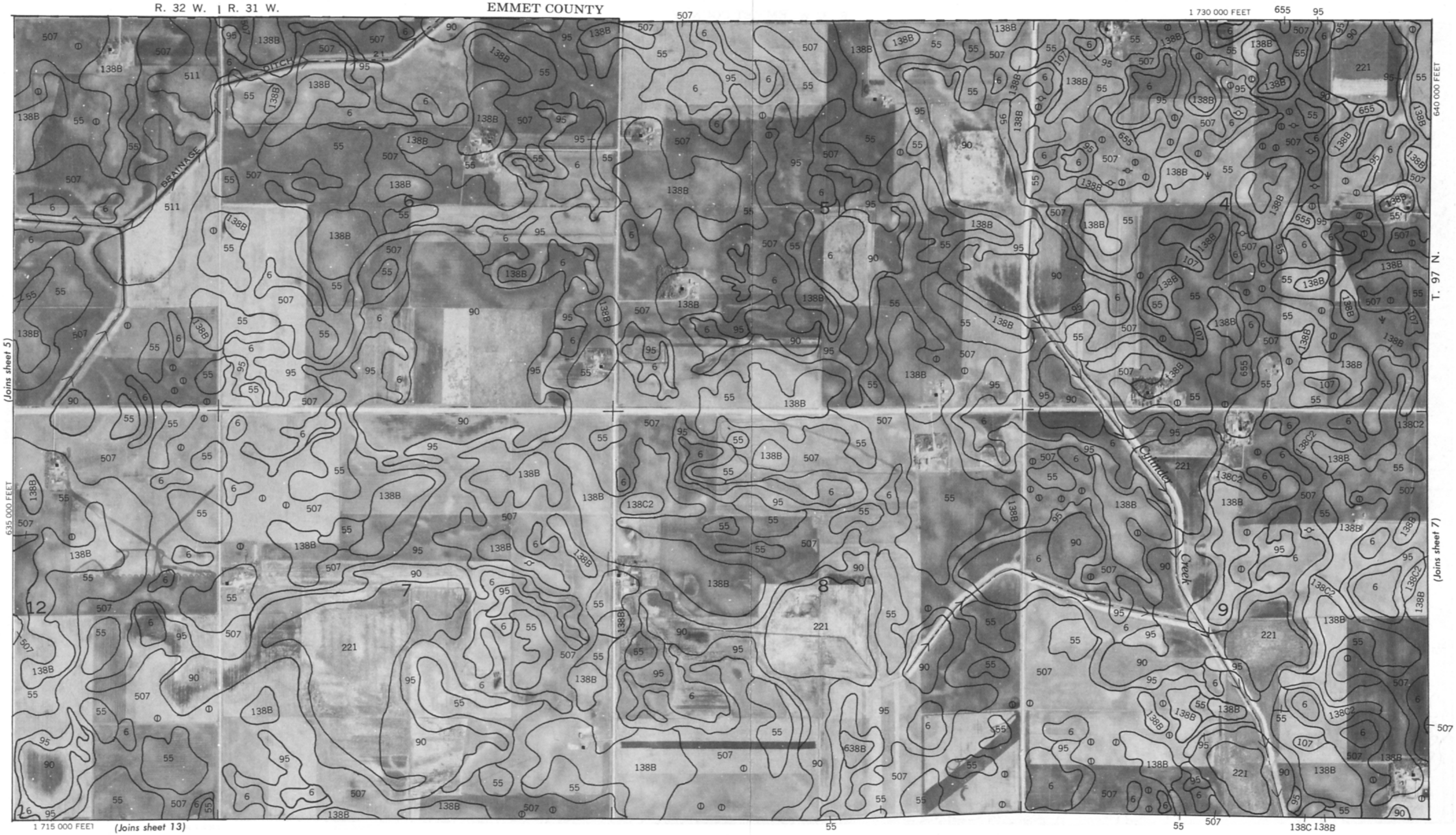


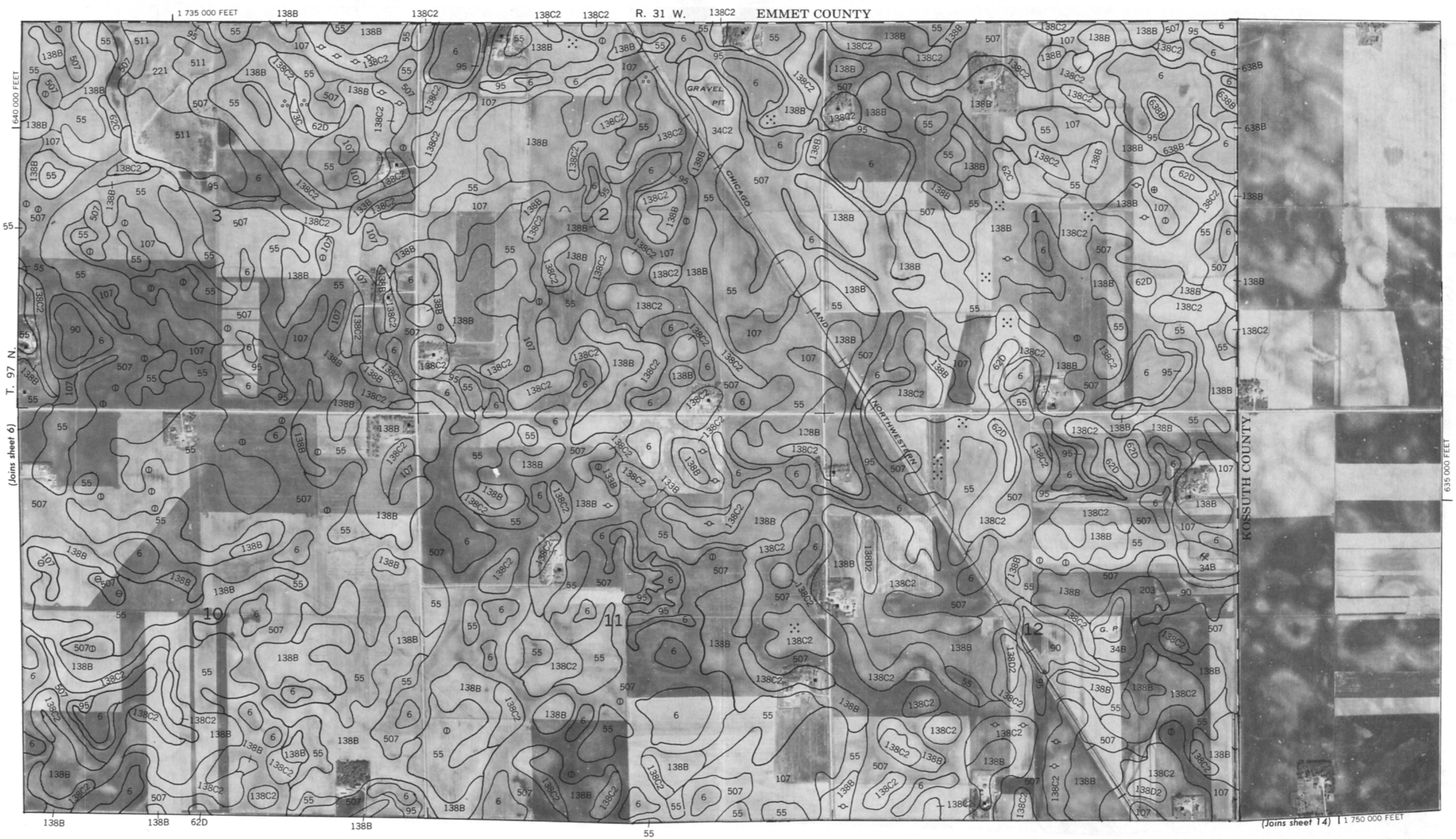
6

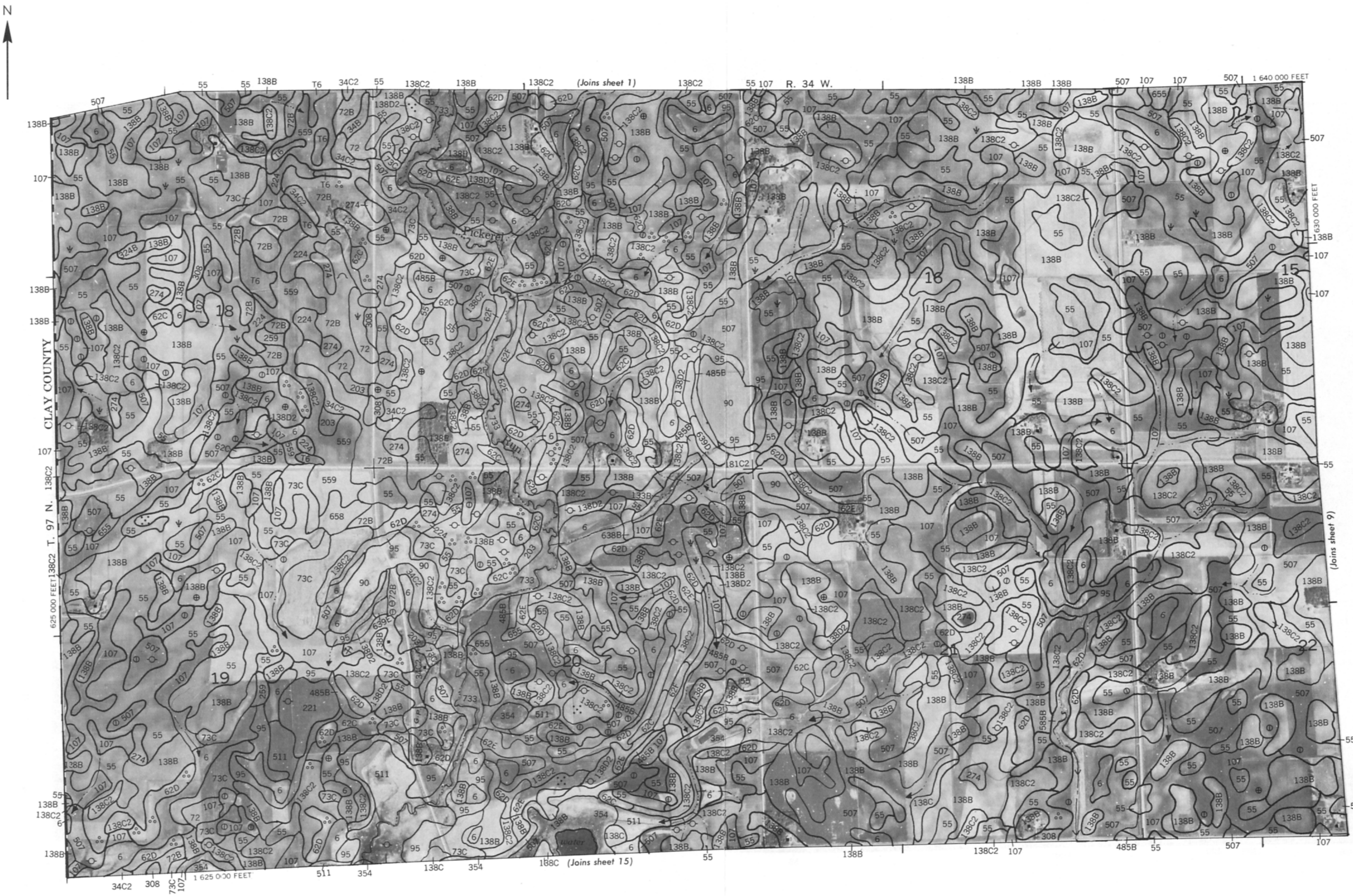
N

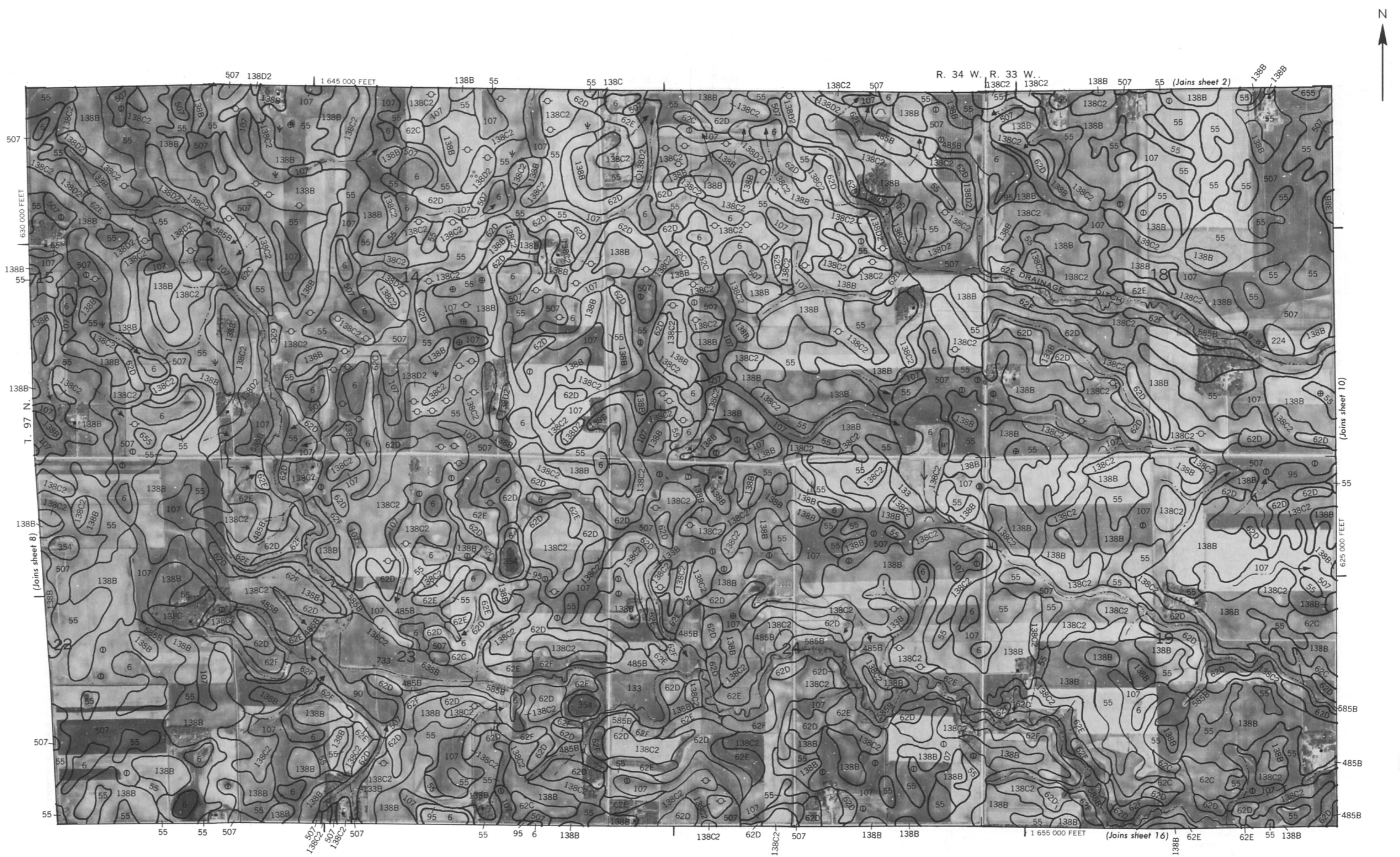

R. 32 W.
R. 31 W.
EMMET COUNTY
1 730 000 FEET
640 000 FEET
T. 97 N.
(Joins sheet 7)
(Joins sheet 5)
635 000 FEET
1 715 000 FEET
(Joins sheet 13)
DRAINAGE
DITCH
Cylinder
Creek

7

N

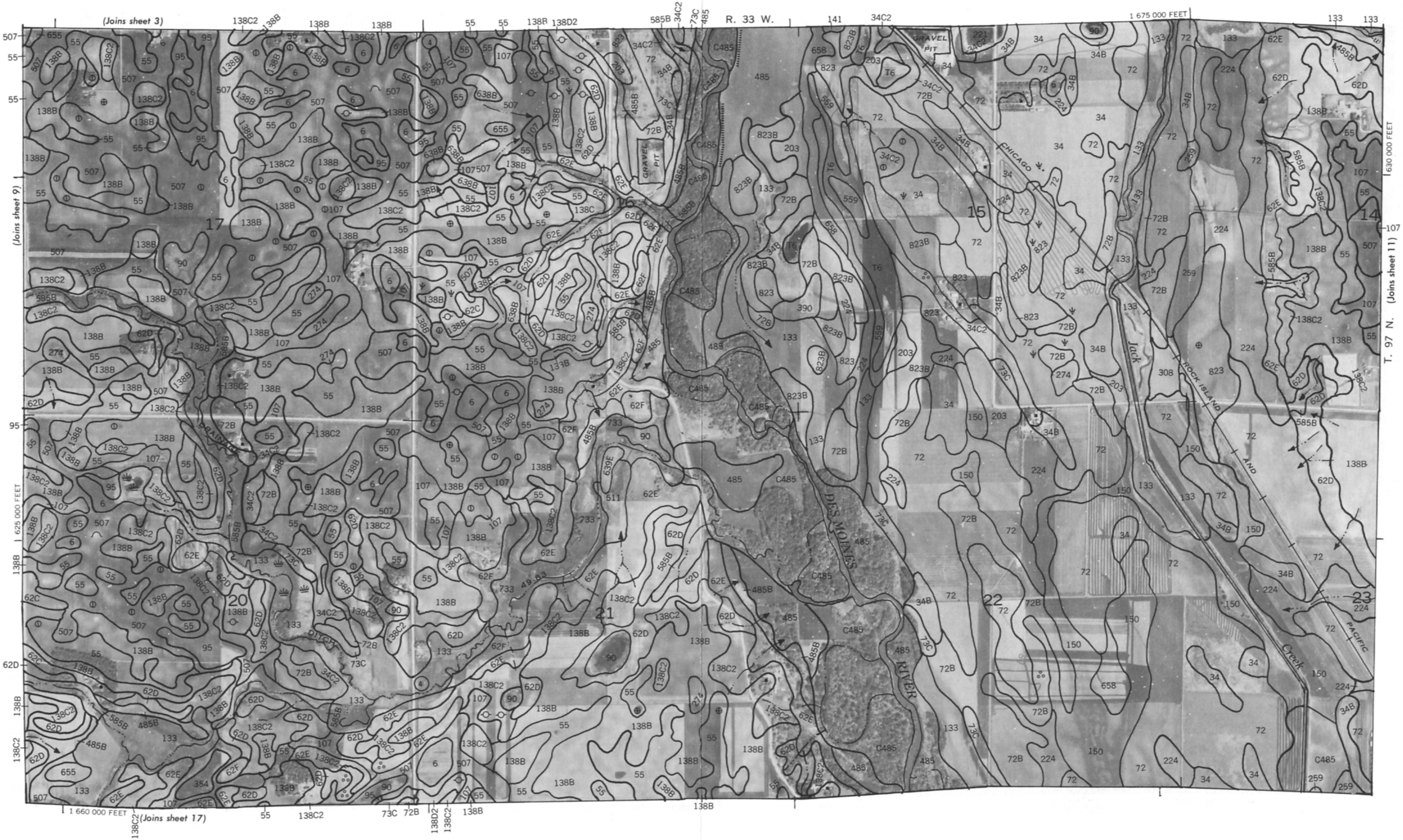

EMMET COUNTY
KOSSUTH COUNTY
R. 31 W.
T. 97 N.
1 735 000 FEET
1 750 000 FEET
640 000 FEET
635 000 FEET
(Joins sheet 6)
(Joins sheet 14)
GRAVEL PIT
G. P.
CHICAGO
AND
NORTHWESTERN
1
2
3
10
11
12


N
(Joins sheet 1)
R. 34 W.
1 640 000 FEET
630 000 FEET
CLAY COUNTY
T. 97 N.
625 000 FEET
(Joins sheet 9)
(Joins sheet 15)
1 625 000 FEET
Pickerel
Run
Water
15
16
17
18
19
20
21
22


9
N
R. 34 W. R. 33 W.
T. 97 N.
(Joins sheet 2)
(Joins sheet 8)
(Joins sheet 10)
(Joins sheet 16)
1 645 000 FEET
1 655 000 FEET
630 000 FEET
625 000 FEET
DRAINAGE DITCH
14
15
18
19
22
23
24

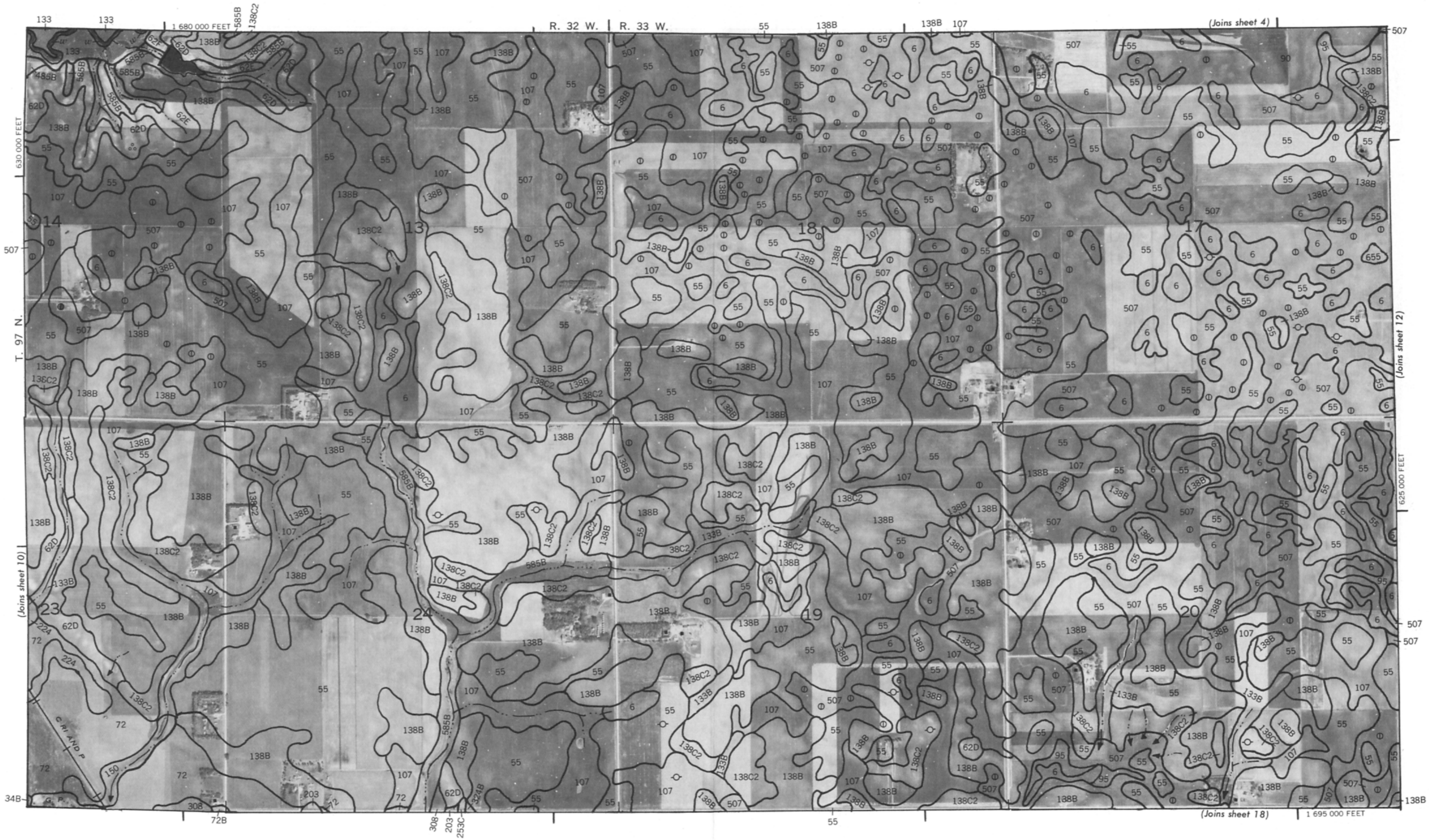
10

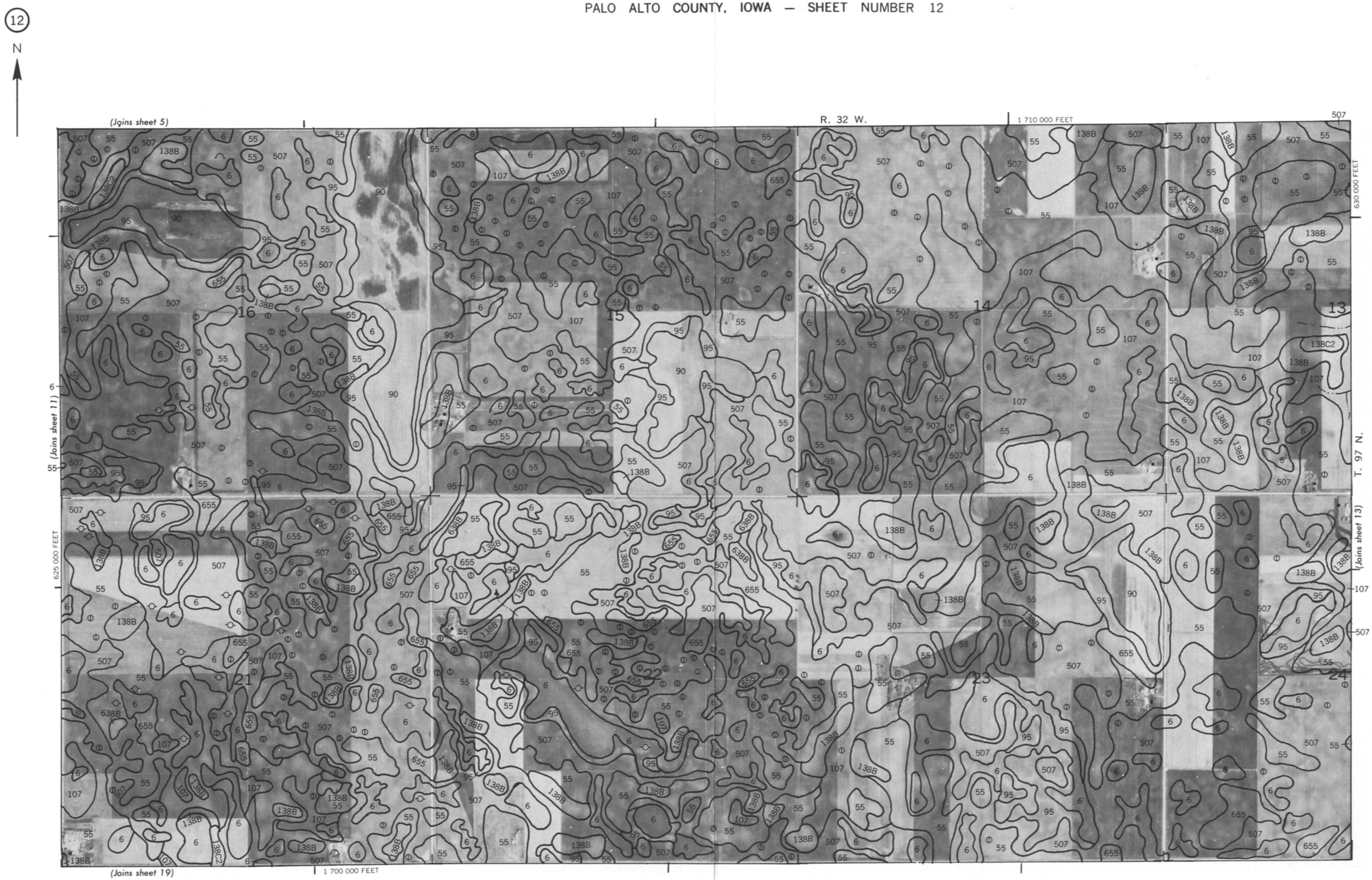
N

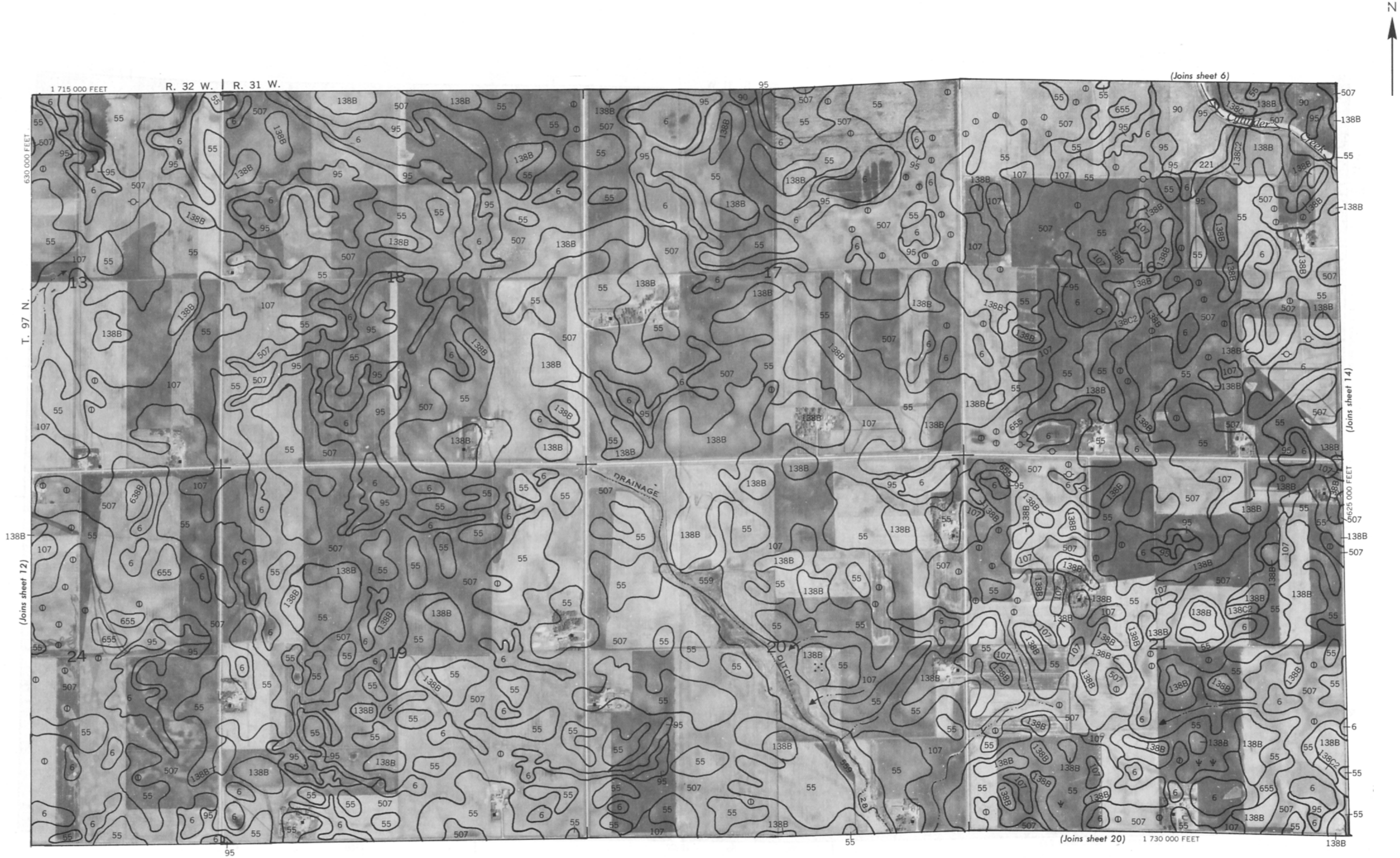

(Joins sheet 3)
R. 33 W.
1 675 000 FEET
630 000 FEET
(Joins sheet 11)
T. 97 N.
(Joins sheet 9)
625 000 FEET
1 660 000 FEET
(Joins sheet 17)
GRAVEL PIT
DRAINAGE
DITCH
DES MOINES
RIVER
CHICAGO
ROCK ISLAND
AND
PACIFIC
Jack
Creek
17
16
15
14
20
21
22
23

PALO ALTO COUNTY, IOWA — SHEET NUMBER 11

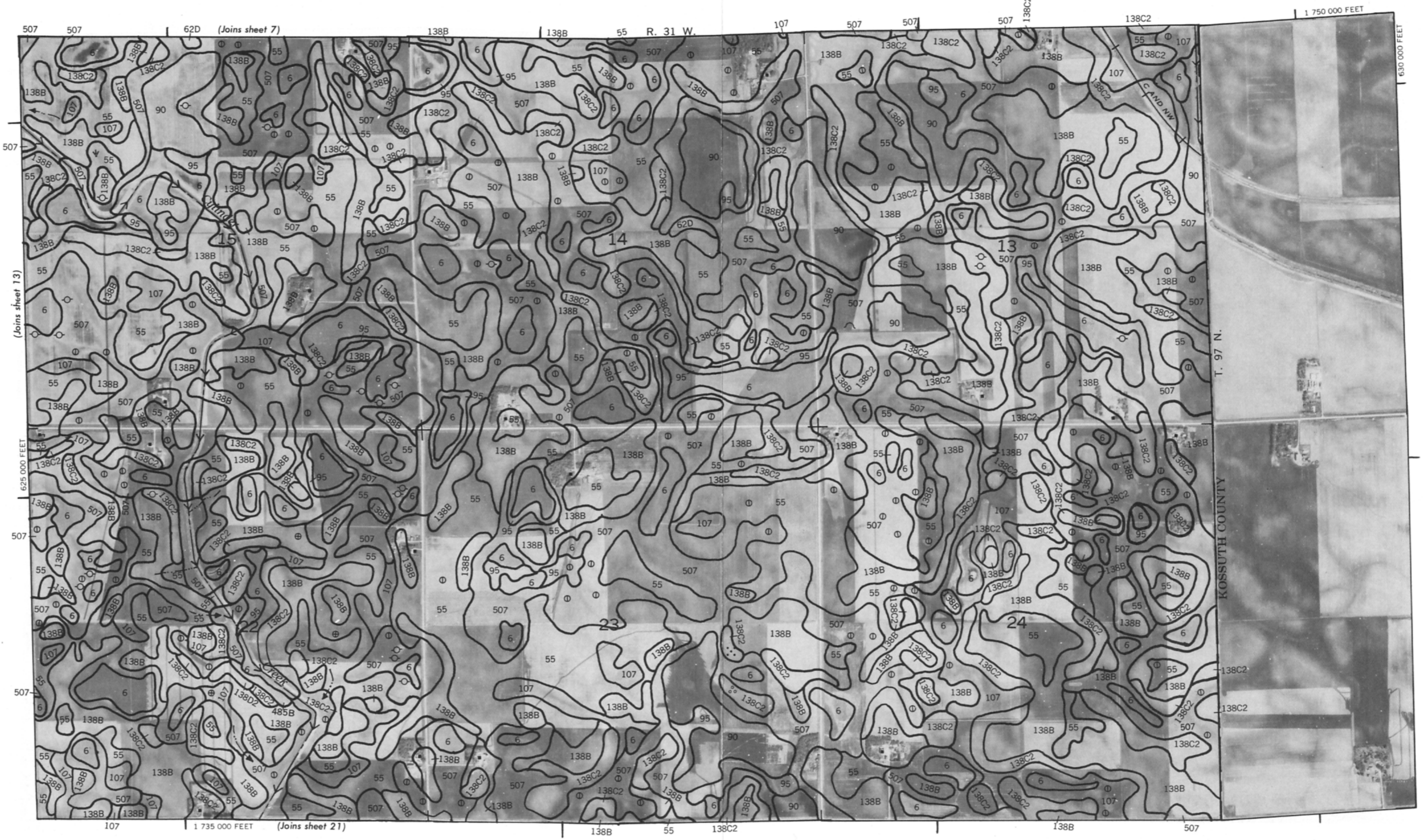
11

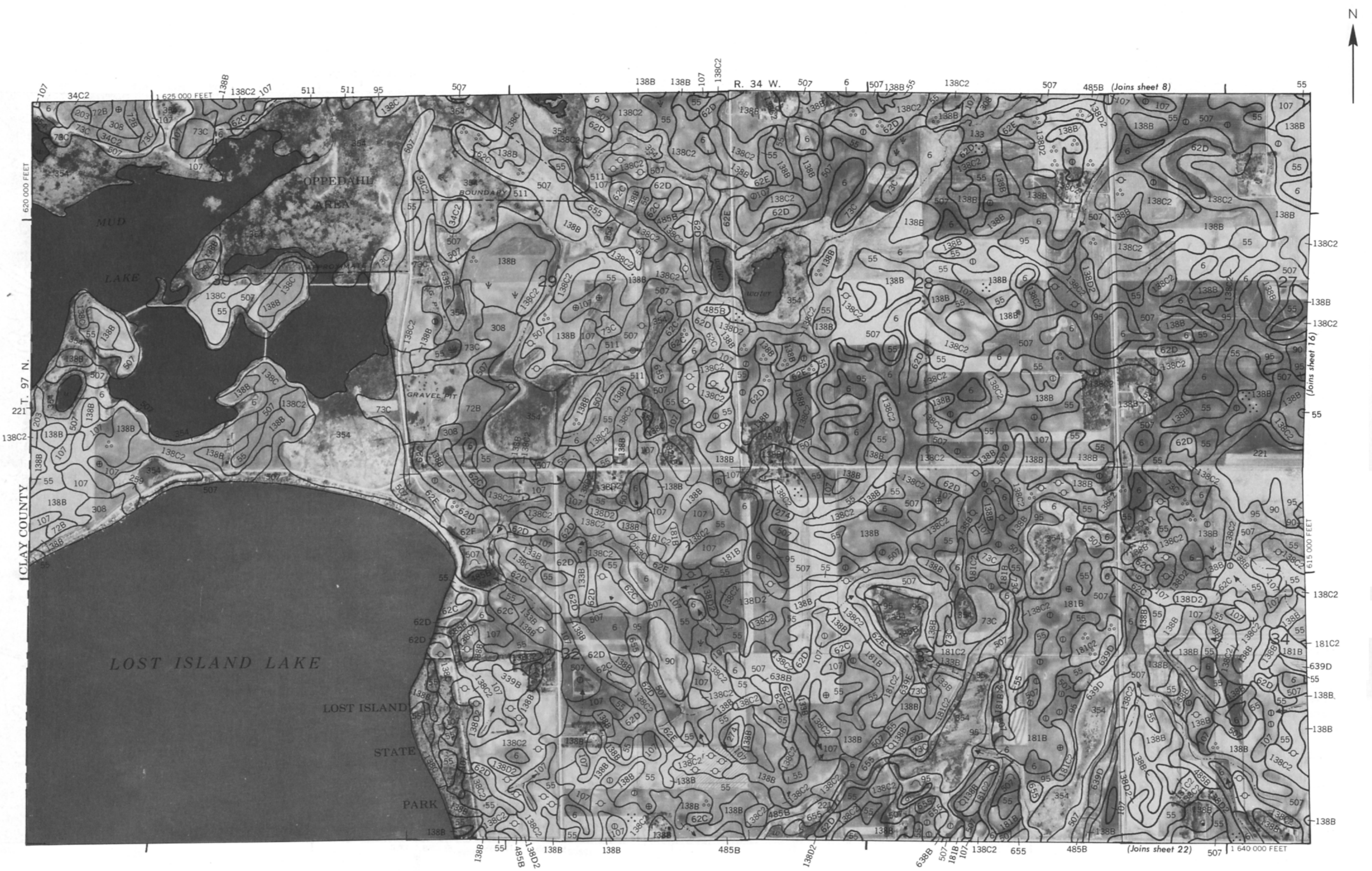



12
N
(Joins sheet 5)
R. 32 W.
1 710 000 FEET
630 000 FEET
(Joins sheet 11)
T. 97 N.
625 000 FEET
(Joins sheet 13)
(Joins sheet 19)
1 700 000 FEET
16
15
14
13
21
22
23
24

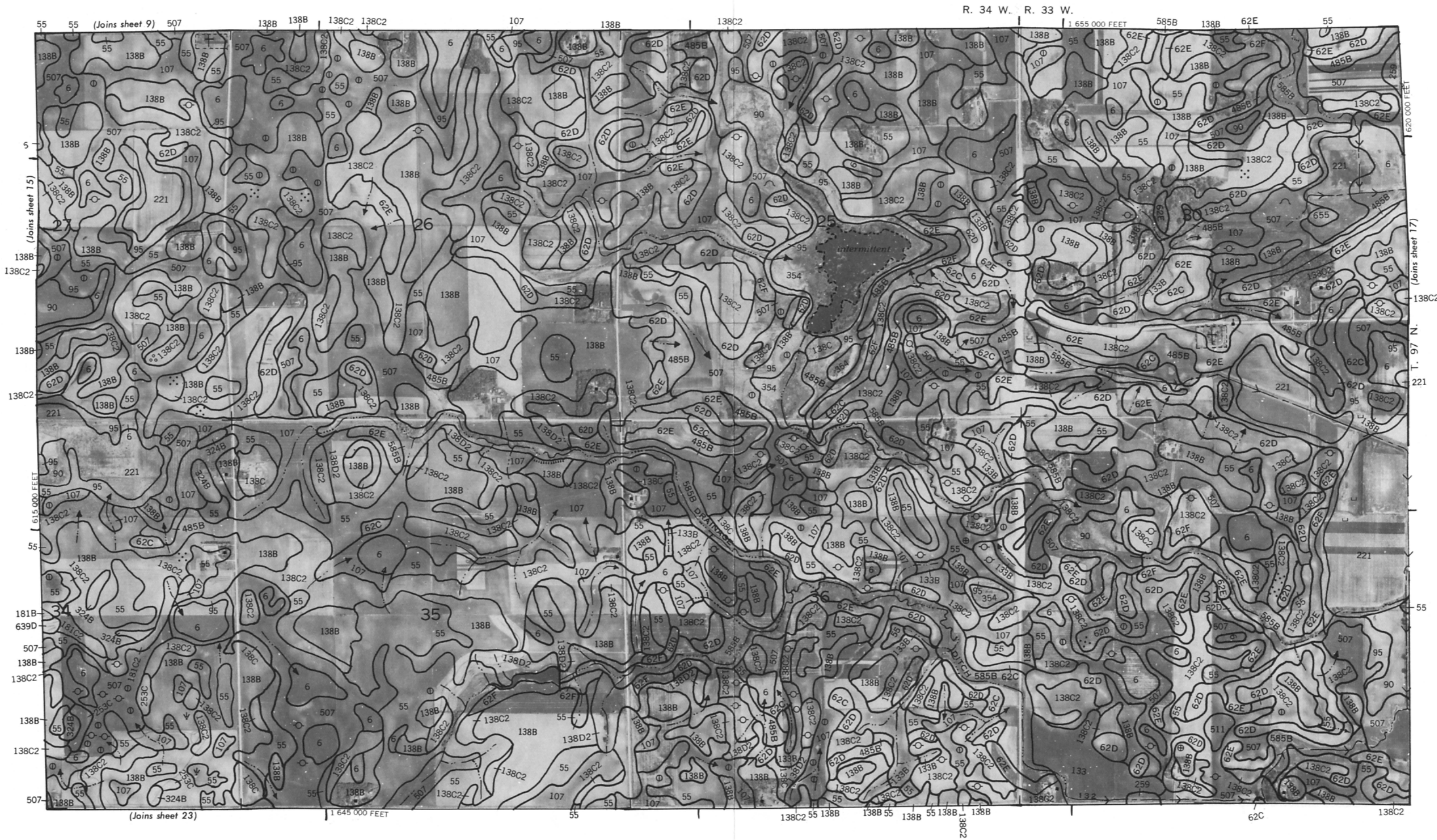

N
(Joins sheet 6)
1 715 000 FEET
R. 32 W.
R. 31 W.
630 000 FEET
T. 97 N.
(Joins sheet 12)
(Joins sheet 14)
625 000 FEET
(Joins sheet 20)
1 730 000 FEET
DRAINAGE
DITCH
Cylinder
Creek
13
18
17
16
24
19
20
21

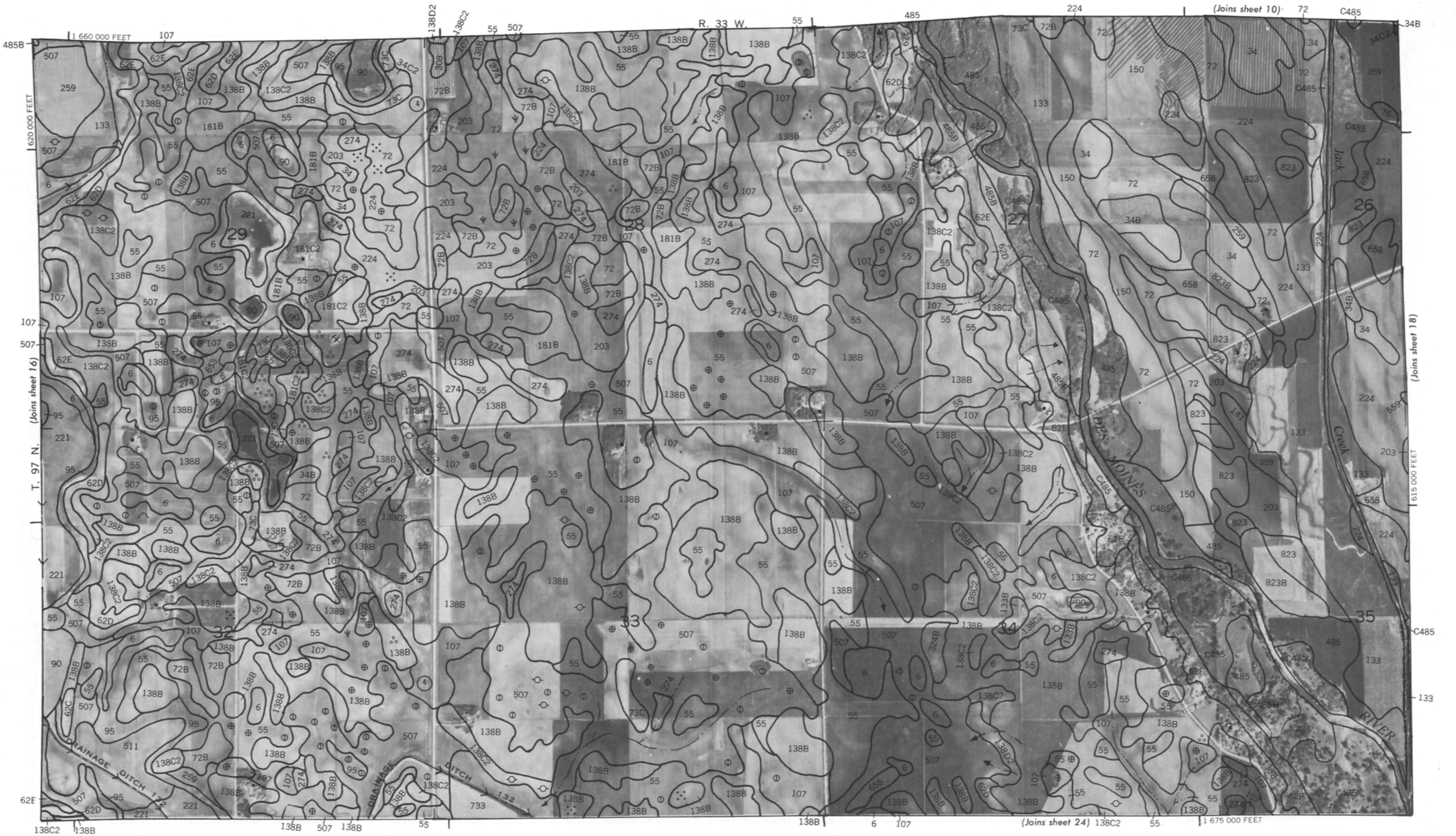
N

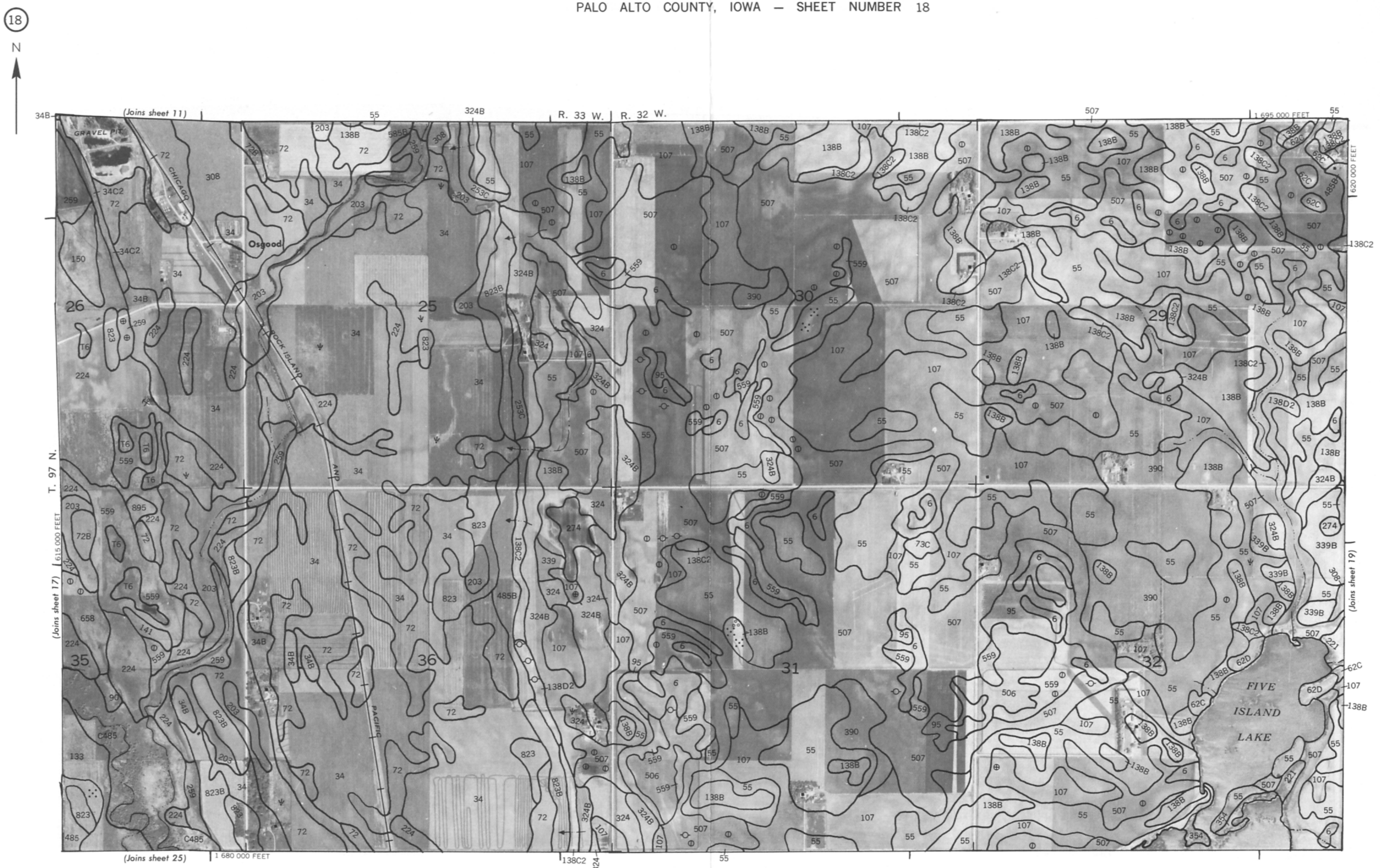

(Joins sheet 7)
(Joins sheet 13)
(Joins sheet 21)
R. 31 W.
T. 97 N.
KOSSUTH COUNTY
1 750 000 FEET
630 000 FEET
625 000 FEET
1 735 000 FEET
C AND NW
Cylinder Creek
14
13
15
23
24
22


R. 34 W.
(Joins sheet 8)
(Joins sheet 16)
(Joins sheet 22)
T. 97 N.
CLAY COUNTY
MUD LAKE
OPPEDAHL AREA
BOUNDARY
GRAVEL PIT
water
LOST ISLAND LAKE
LOST ISLAND STATE PARK
1 625 000 FEET
1 640 000 FEET
620 000 FEET
615 000 FEET
29
28
27
30
32
34

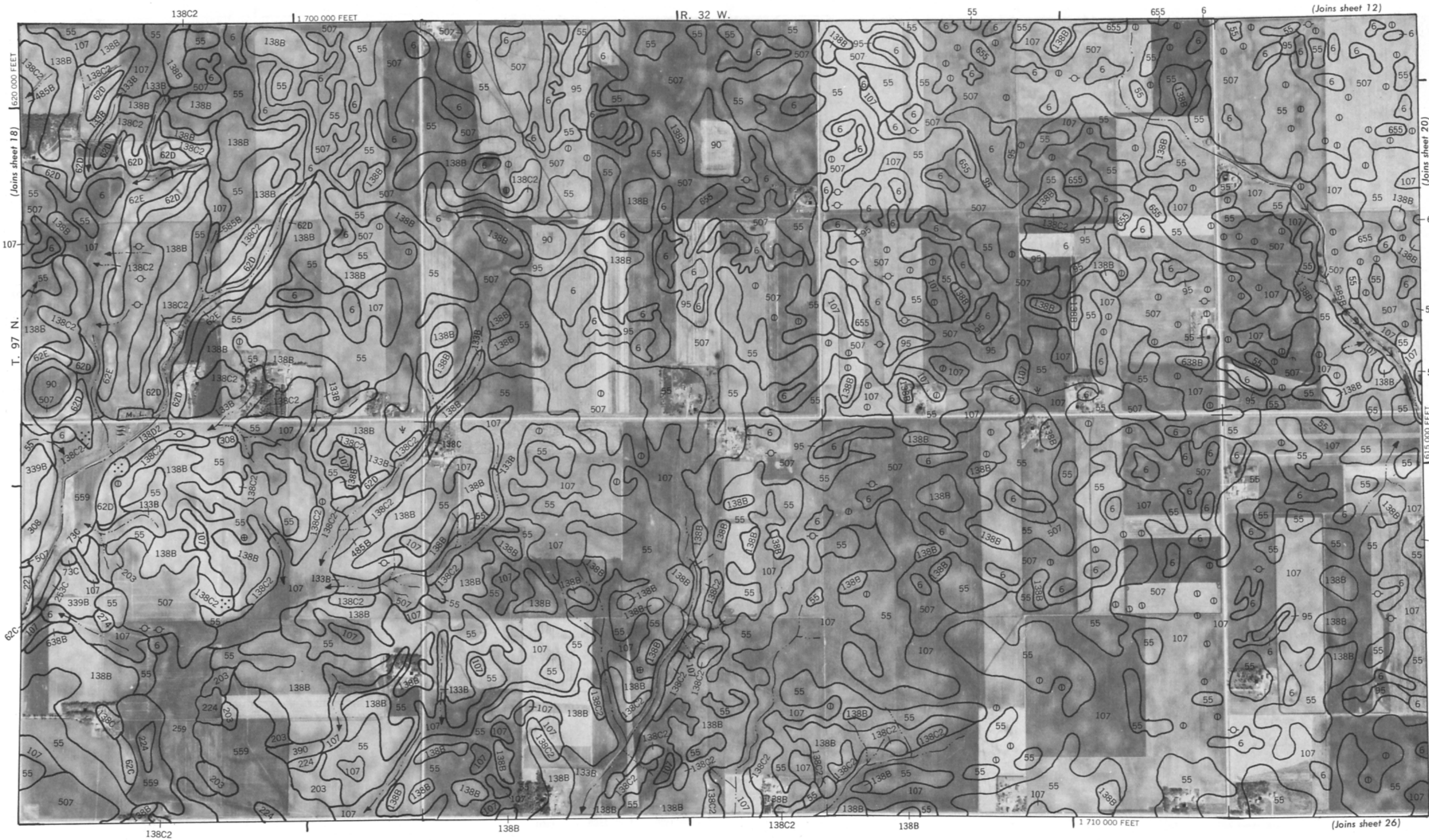
N

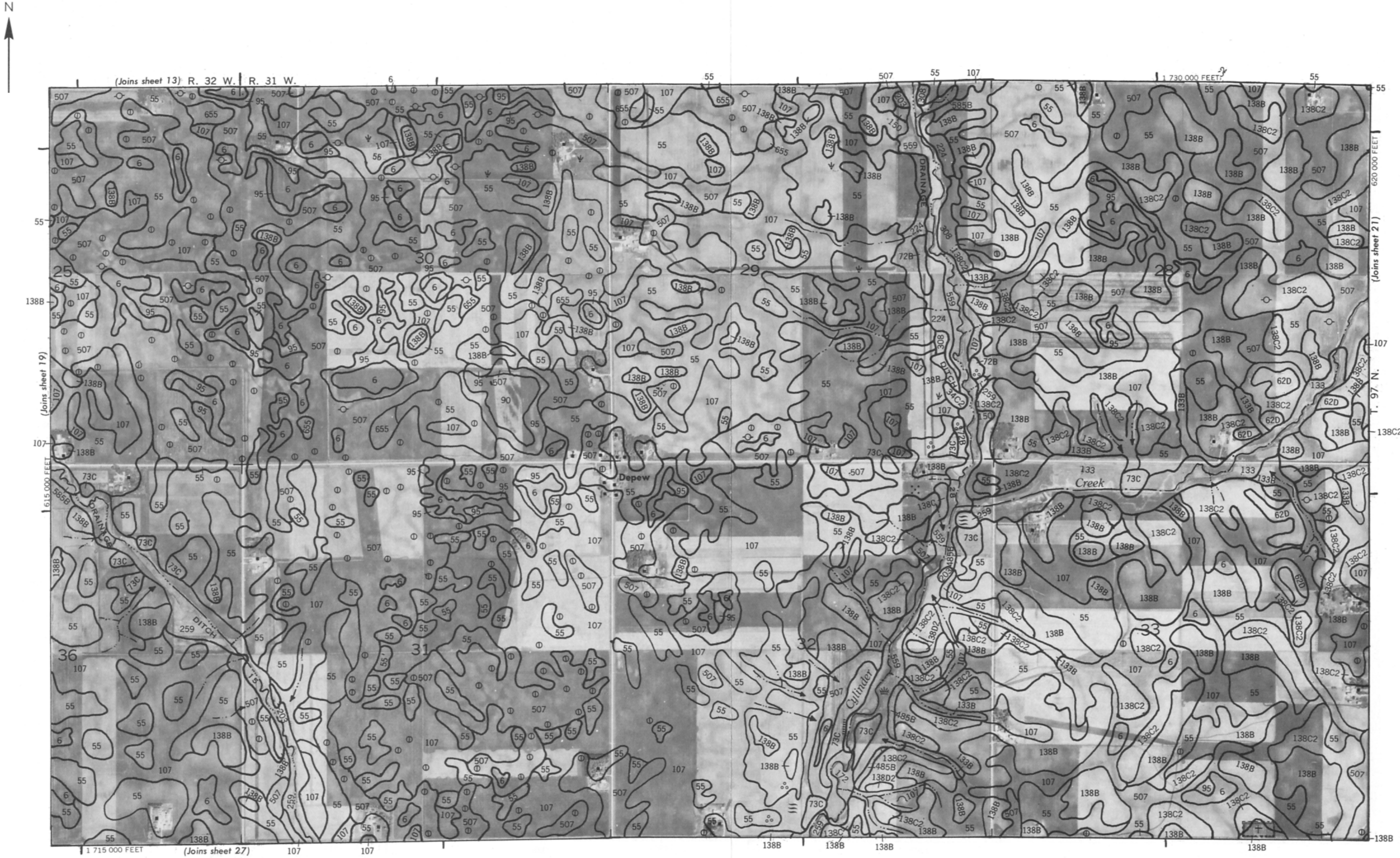

(Joins sheet 9)
R. 34 W.
R. 33 W.
1 655 000 FEET
620 000 FEET
(Joins sheet 15)
(Joins sheet 17)
T. 97 N.
615 000 FEET
intermittent
DRAINAGE
DITCH
27
26
25
30
34
35
36
31
1 645 000 FEET
(Joins sheet 23)


17
N
(Joins sheet 10)
(Joins sheet 16)
(Joins sheet 18)
(Joins sheet 24)
R. 33 W.
T. 97 N.
1 660 000 FEET
1 675 000 FEET
620 000 FEET
615 000 FEET
DES MOINES RIVER
Jack Creek
DRAINAGE DITCH 132
DRAINAGE DITCH 132
26
27
28
29
32
33
34
35


18
N
(Joins sheet 11)
(Joins sheet 17)
(Joins sheet 19)
(Joins sheet 25)
R. 33 W.
R. 32 W.
T. 97 N.
1 695 000 FEET
620 000 FEET
615 000 FEET
1 680 000 FEET
GRAVEL PIT
Osgood
CHICAGO
ROCK ISLAND
AND
PACIFIC
FIVE
ISLAND
LAKE
26
25
30
29
35
36
31
32

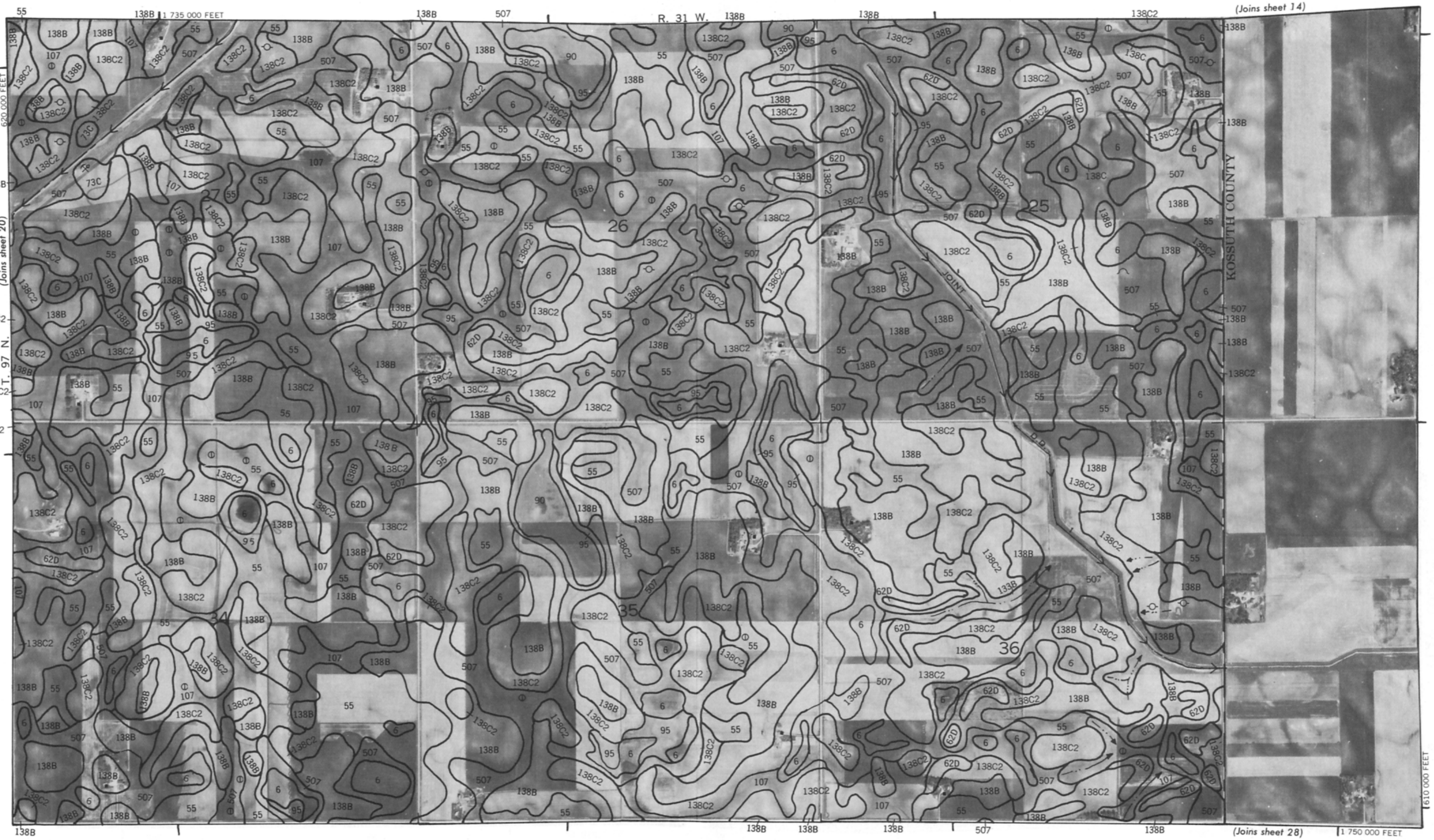
N


(Joins sheet 12)
R. 32 W.
1 700 000 FEET
620 000 FEET
(Joins sheet 18)
T. 97 N.
(Joins sheet 20)
615 000 FEET
1 710 000 FEET
(Joins sheet 26)


N
(Joins sheet 13)
R. 32 W.
R. 31 W.
1 730 000 FEET
620 000 FEET
(Joins sheet 21)
T. 97 N.
(Joins sheet 19)
615 000 FEET
1 715 000 FEET
(Joins sheet 27)
Depew
Creek
Cylinder
DRAINAGE
DITCH
25
30
29
28
36
31
32
33

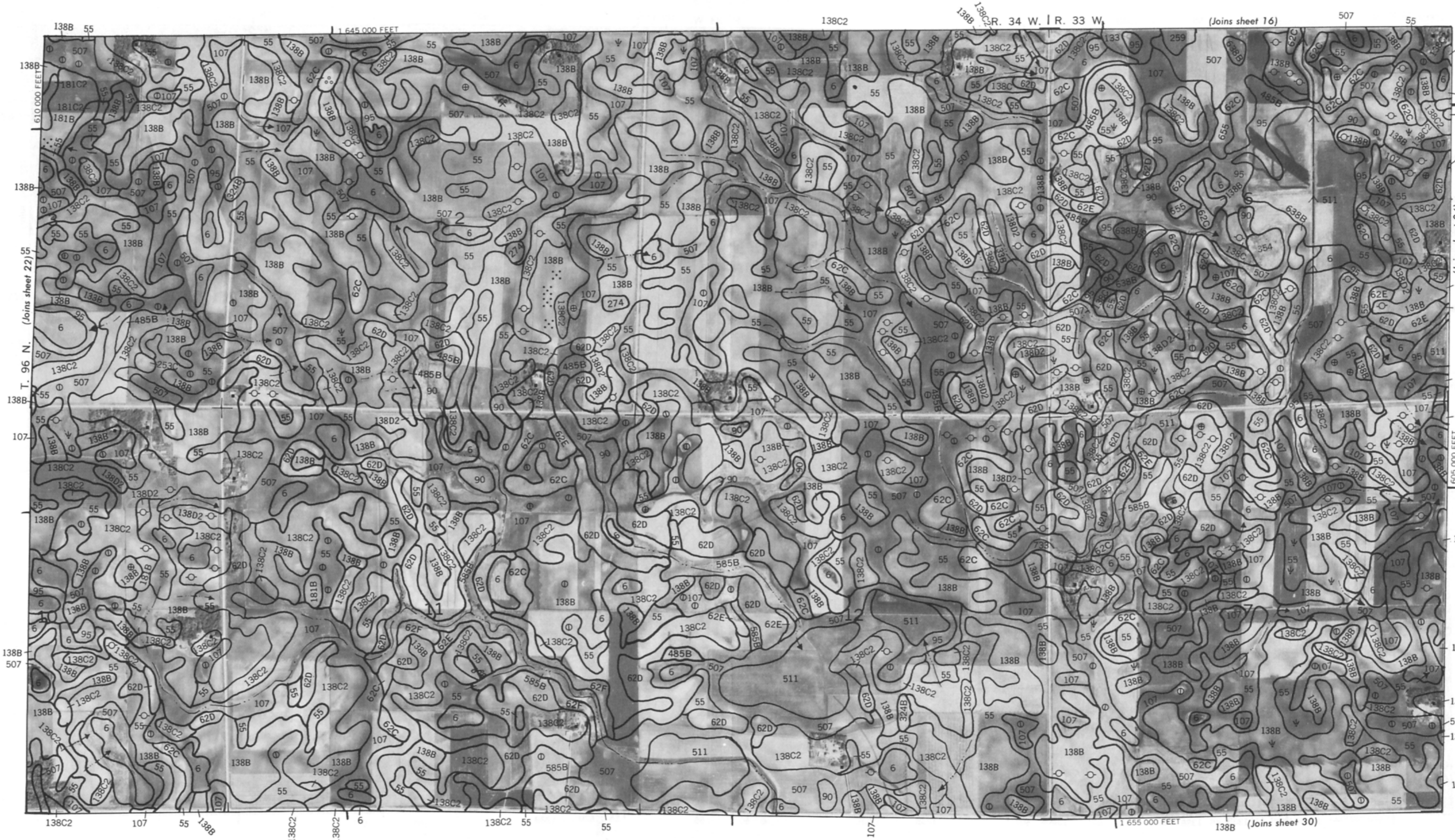
21

N


(Joins sheet 14)
(Joins sheet 20)
(Joins sheet 28)
1 735 000 FEET
1 750 000 FEET
620 000 FEET
610 000 FEET
R. 31 W.
T. 97 N.
KOSSUTH COUNTY
JOINT
D.D.
25
26
27
34
35
36

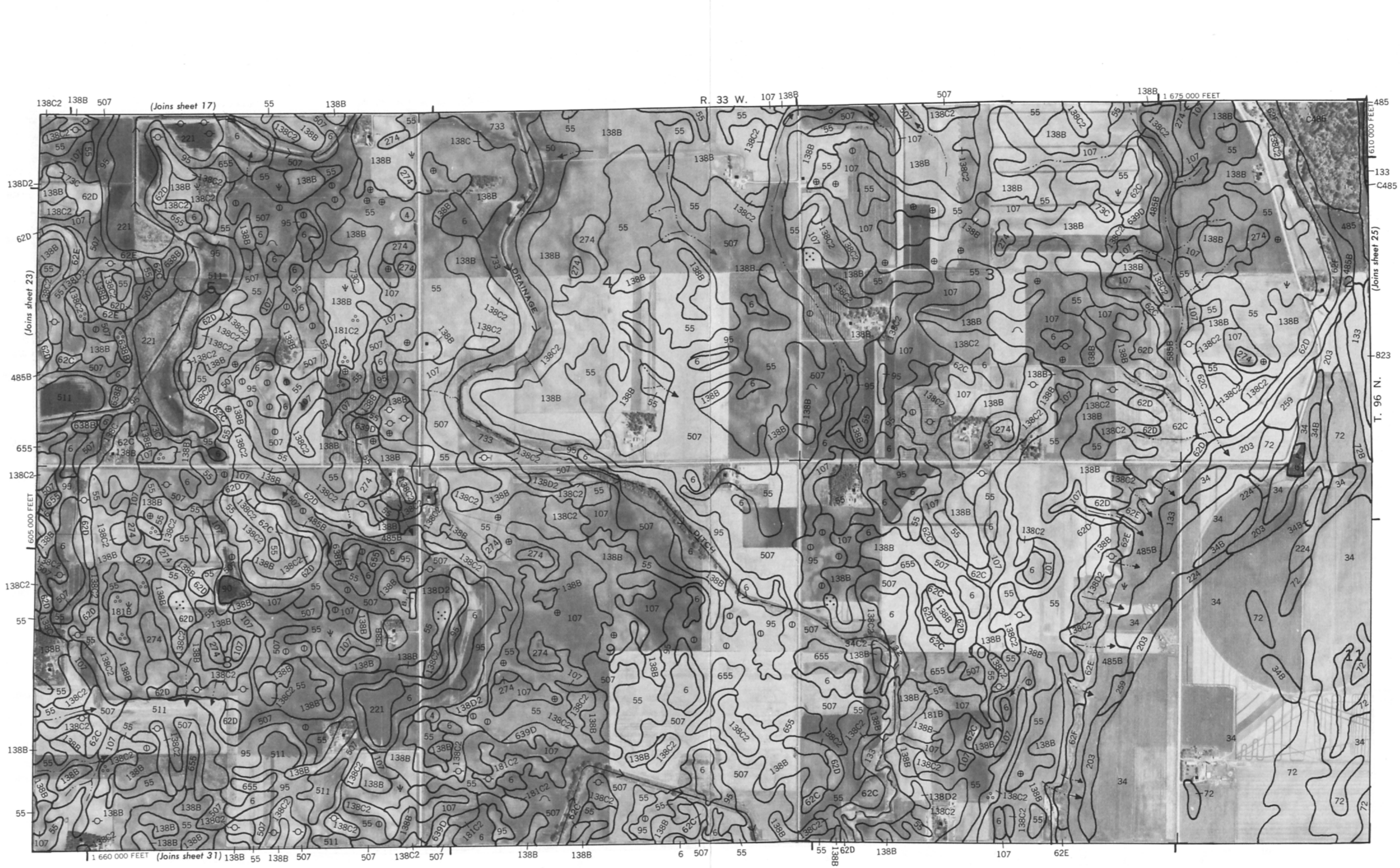

N
(Joins sheet 15)
R. 34 W.
1 640 000 FEET
610 000 FEET
LOST ISLAND LAKE
BLUE WING MARSH
T. 96 N.
605 000 FEET
CLAY COUNTY
(Joins sheet 23)
(Joins sheet 29)
1 625 000 FEET

N

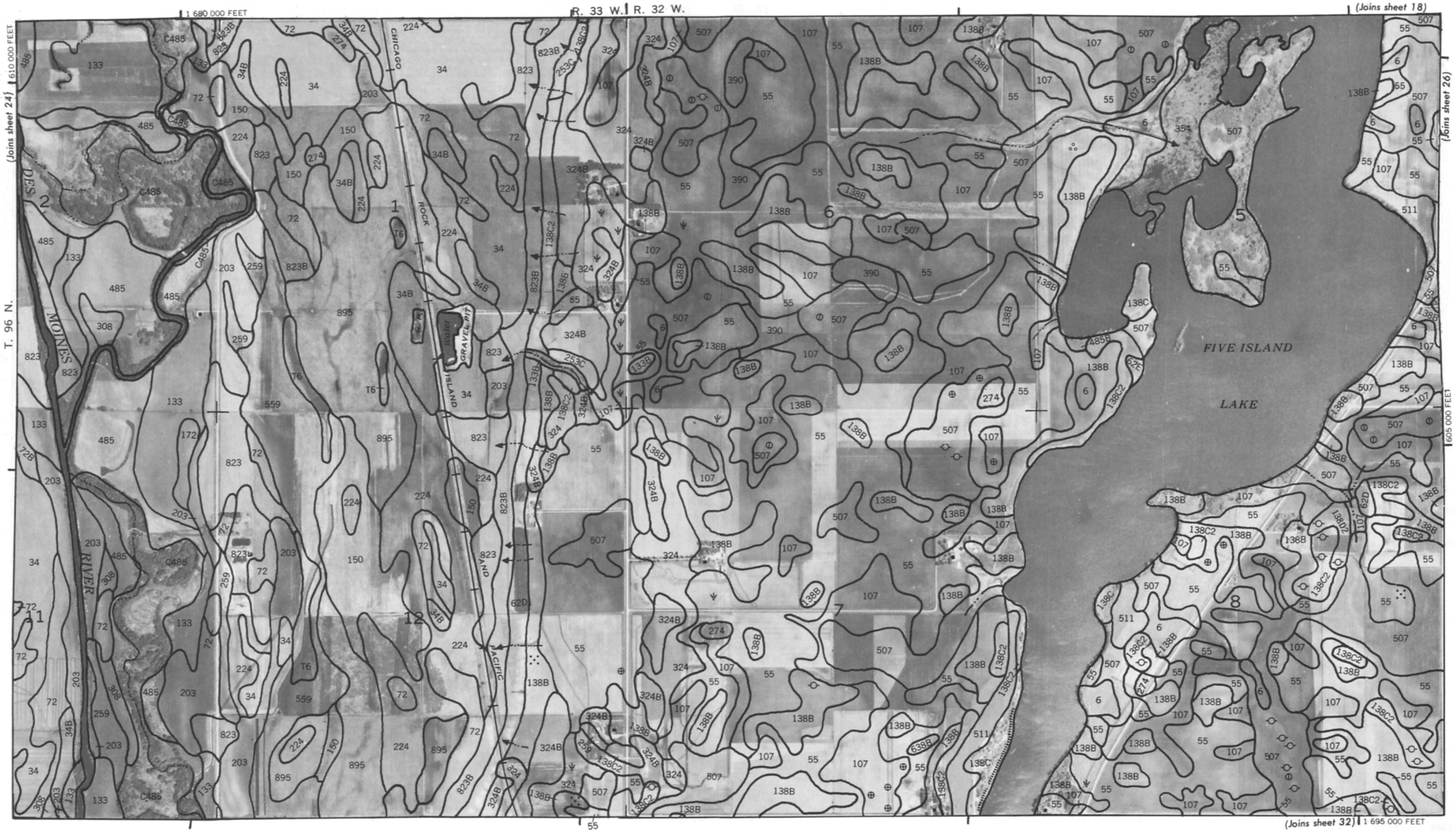

R. 34 W.
R. 33 W.
T. 96 N.
(Joins sheet 16)
(Joins sheet 22)
(Joins sheet 24)
(Joins sheet 30)
1 645 000 FEET
1 655 000 FEET
610 000 FEET
605 000 FEET

24

N


(Joins sheet 17)
R. 33 W.
1 675 000 FEET
610 000 FEET
(Joins sheet 23)
(Joins sheet 25)
T. 96 N.
605 000 FEET
1 660 000 FEET
(Joins sheet 31)
DRAINAGE
DITCH

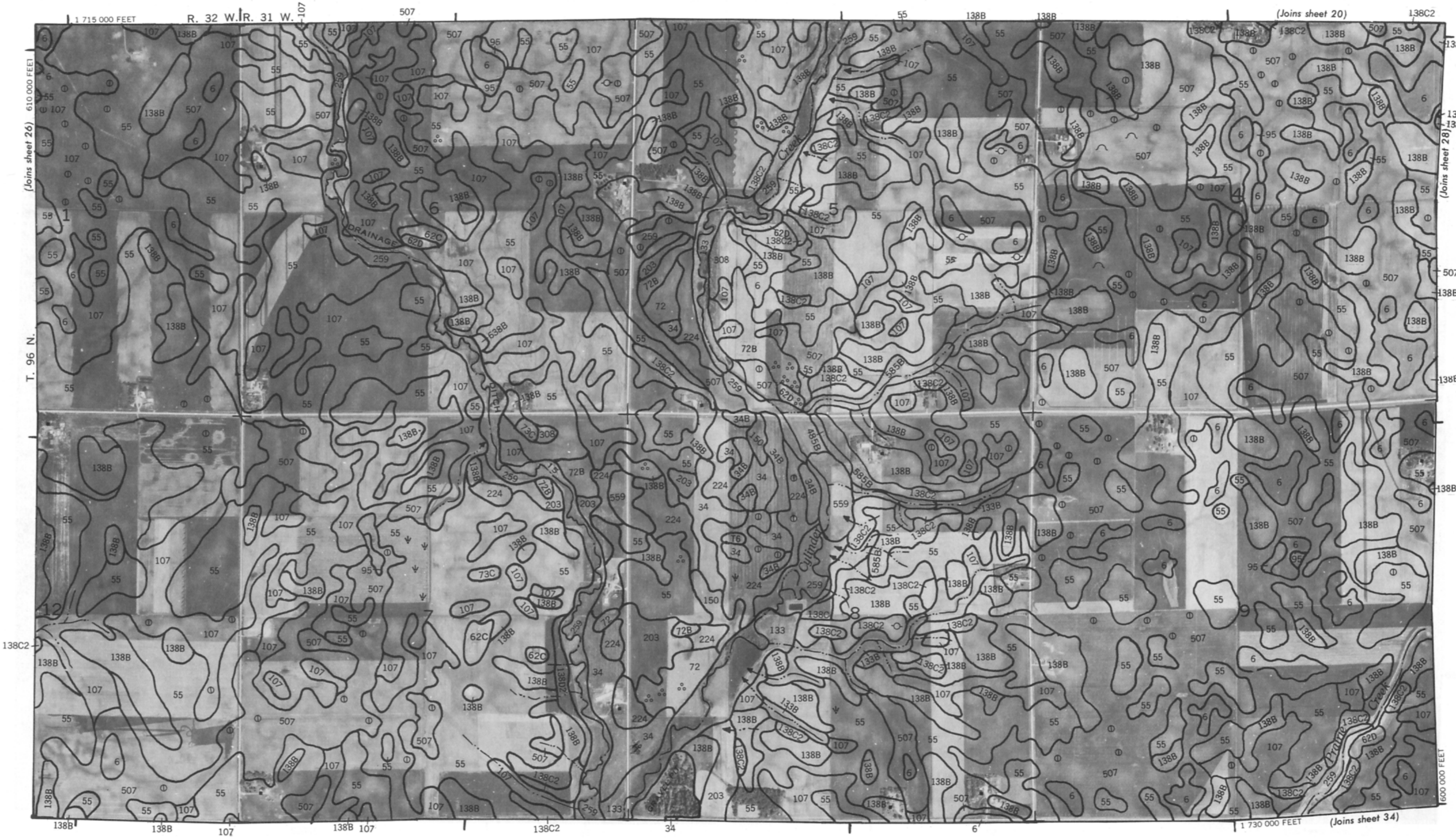
N

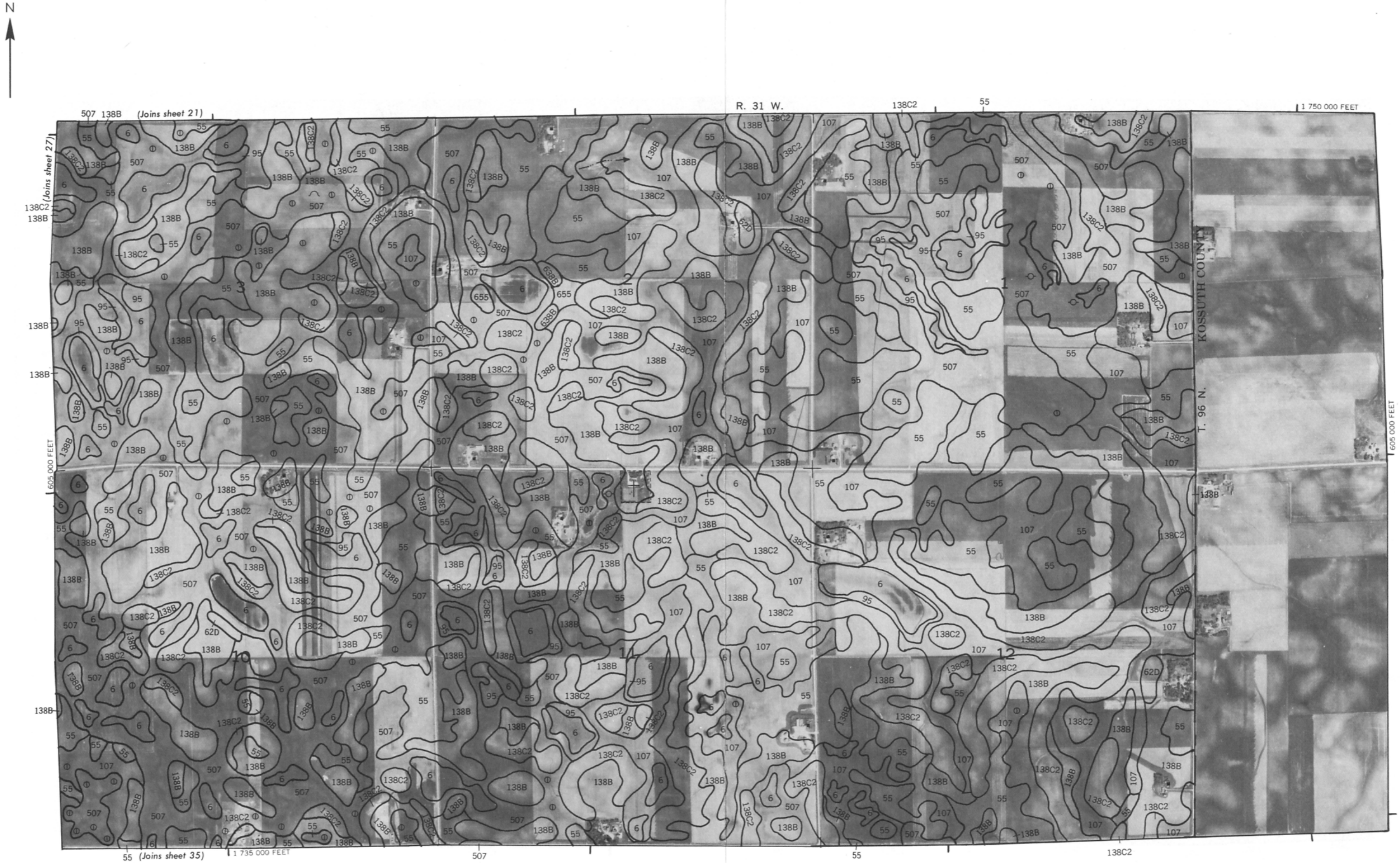

1 680 000 FEET
R. 33 W.
R. 32 W.
(Joins sheet 18)
(Joins sheet 24)
(Joins sheet 26)
(Joins sheet 32)
1 695 000 FEET
610 000 FEET
605 000 FEET
T. 96 N.
DES MOINES RIVER
CHICAGO ROCK ISLAND AND PACIFIC
WATER
GRAVEL PIT
FIVE ISLAND LAKE

PALO ALTO COUNTY, IOWA — SHEET NUMBER 26

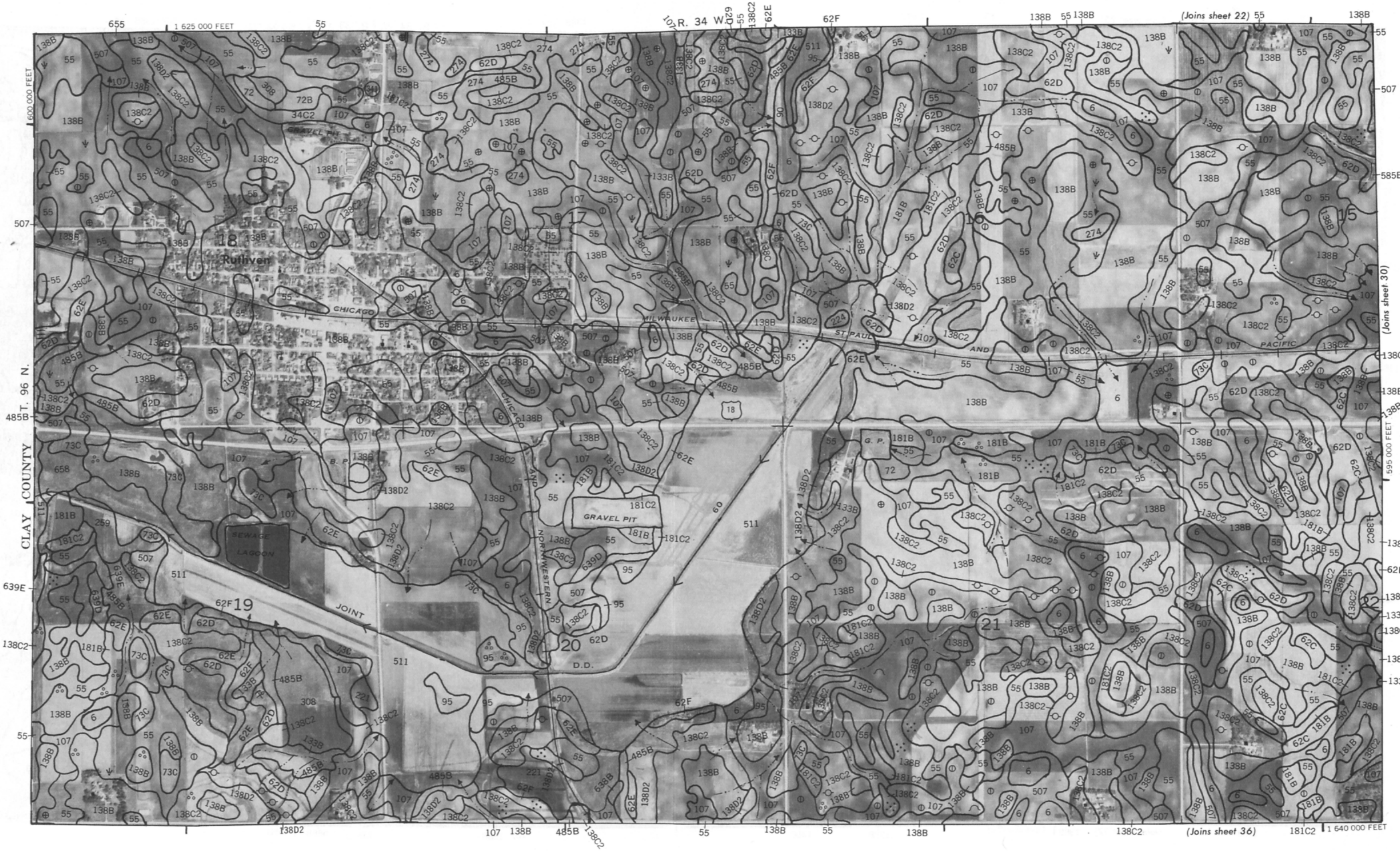
N

N


1 715 000 FEET
R. 32 W.
R. 31 W.
(Joins sheet 20)
(Joins sheet 26)
(Joins sheet 28)
(Joins sheet 34)
610 000 FEET
T. 96 N.
1 730 000 FEET
600 000 FEET
DRAINAGE
DITCH
Creek
Cylinder
Prairie Creek

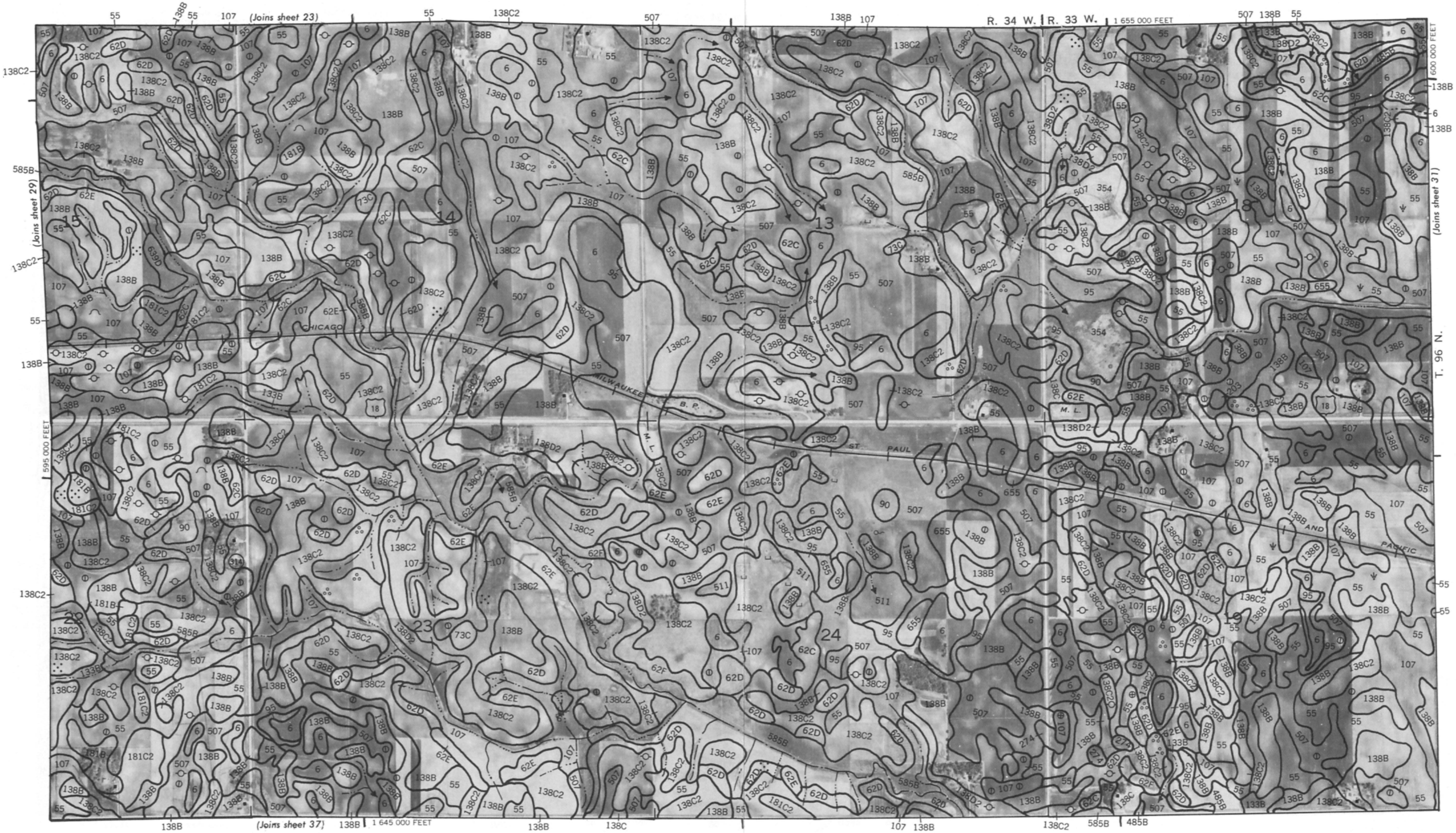

N
R. 31 W.
(Joins sheet 21)
(Joins sheet 27)
(Joins sheet 35)
1 750 000 FEET
605 000 FEET
605 000 FEET
1 735 000 FEET
KOSSUTH COUNTY
T. 96 N.

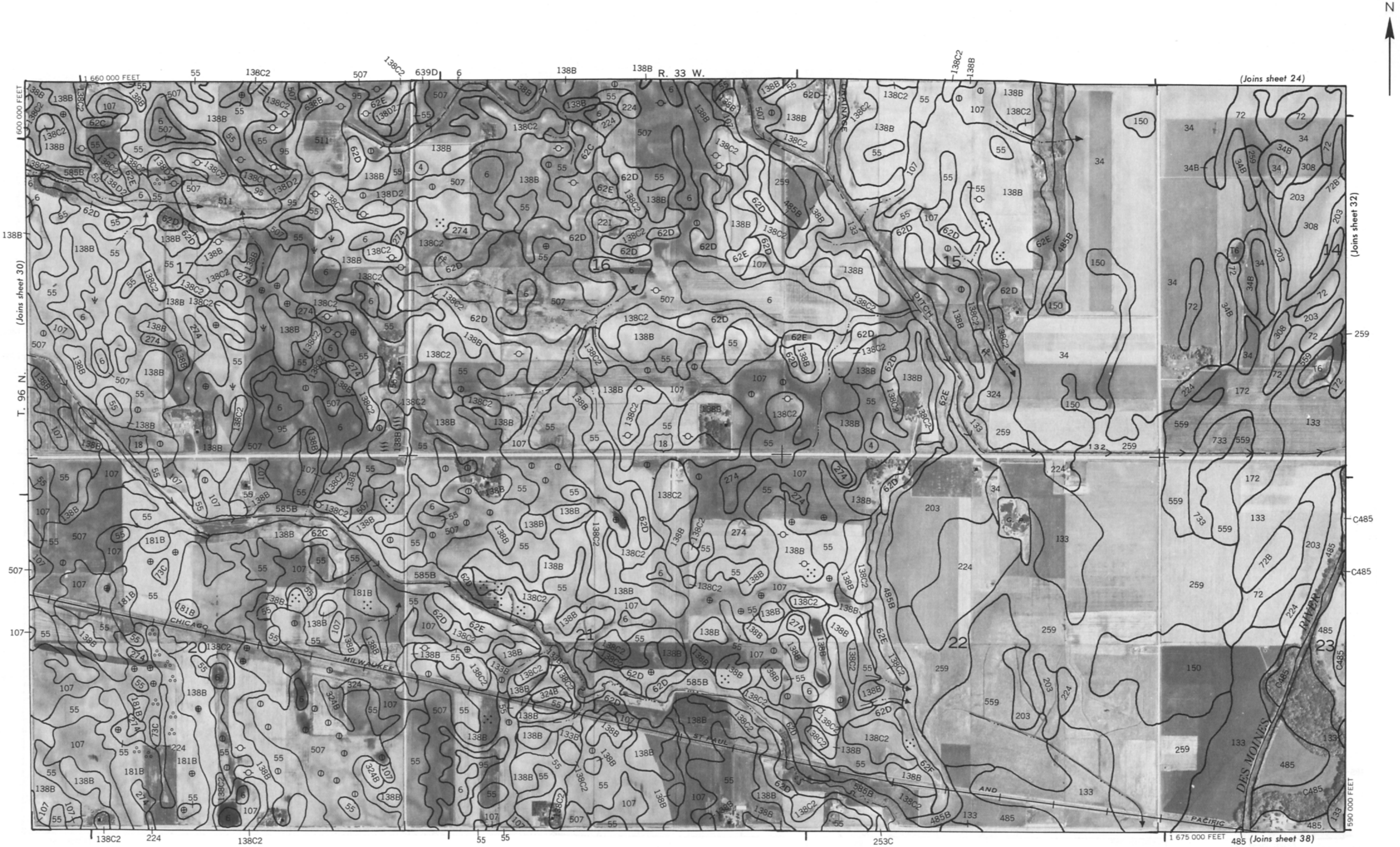
N

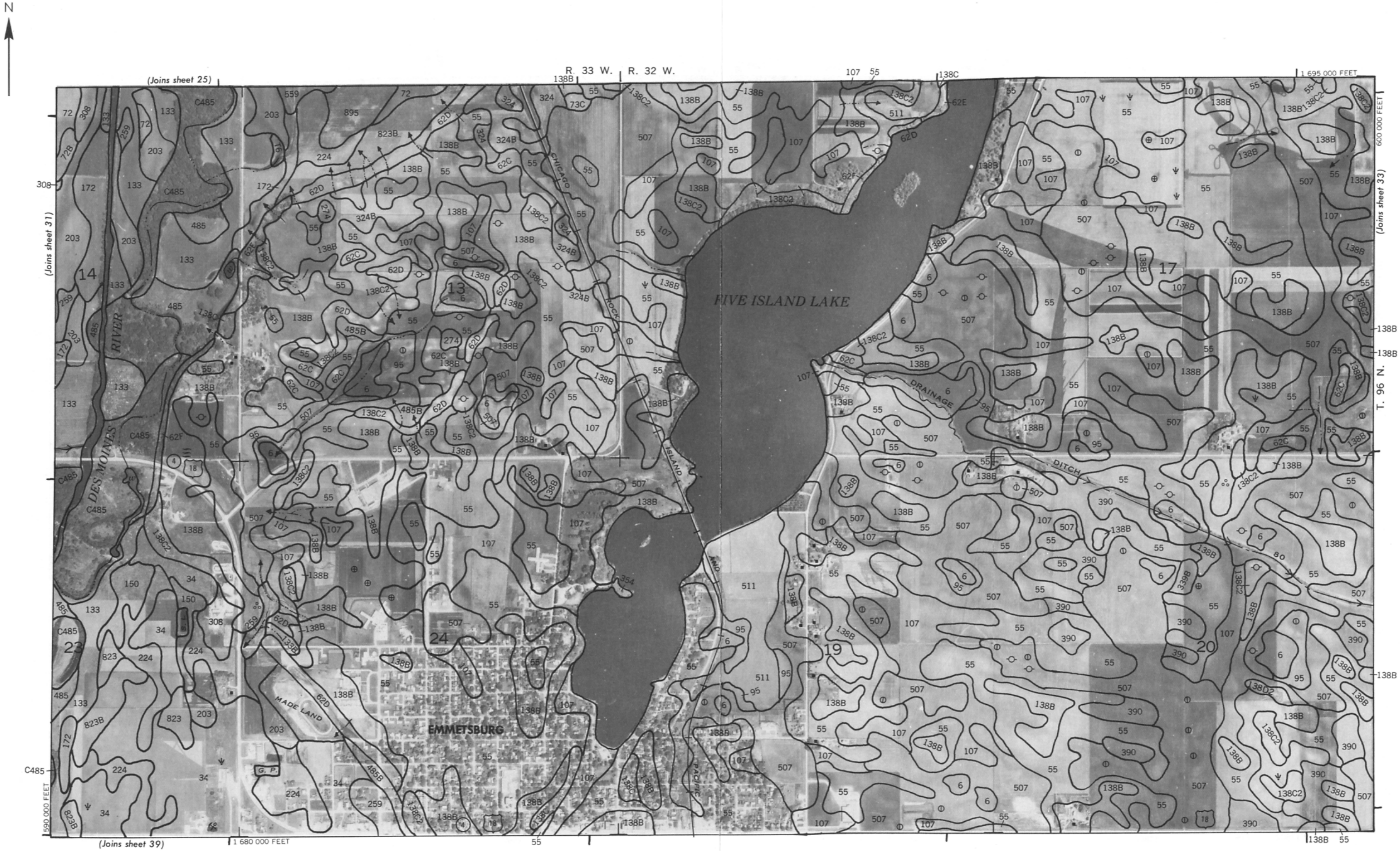

(Joins sheet 22)
(Joins sheet 30)
(Joins sheet 36)
R. 34 W.
T. 96 N.
CLAY COUNTY
1 625 000 FEET
1 640 000 FEET
600 000 FEET
595 000 FEET
Ruthven
CHICAGO
MILWAUKEE
ST. PAUL
AND
PACIFIC
CHICAGO AND NORTHWESTERN
GRAVEL PIT
SEWAGE LAGOON
JOINT
D.D.
G. P.
B. P.
18
17
16
15
19
20
21
22

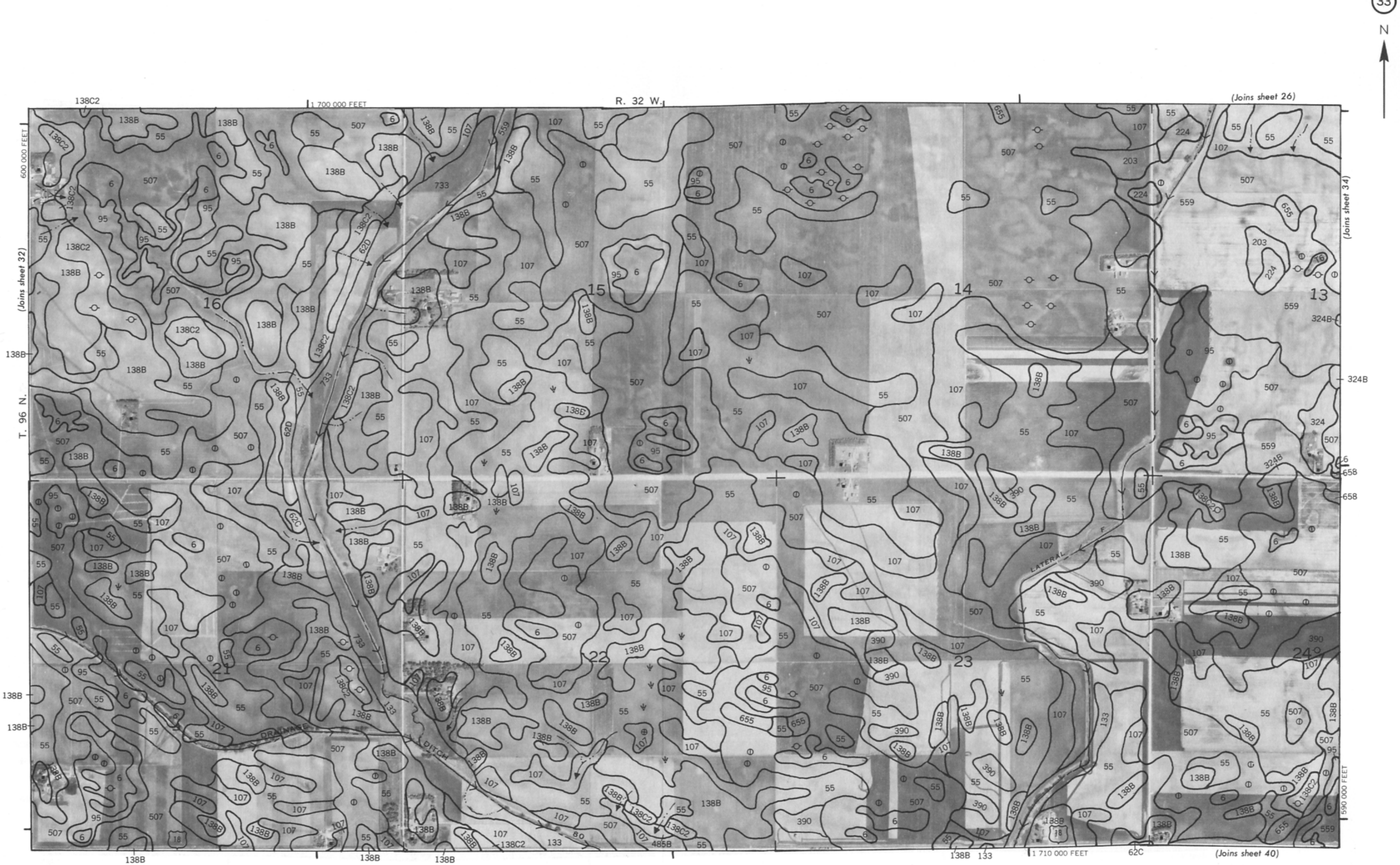
PALO ALTO COUNTY, IOWA — SHEET NUMBER 30

N

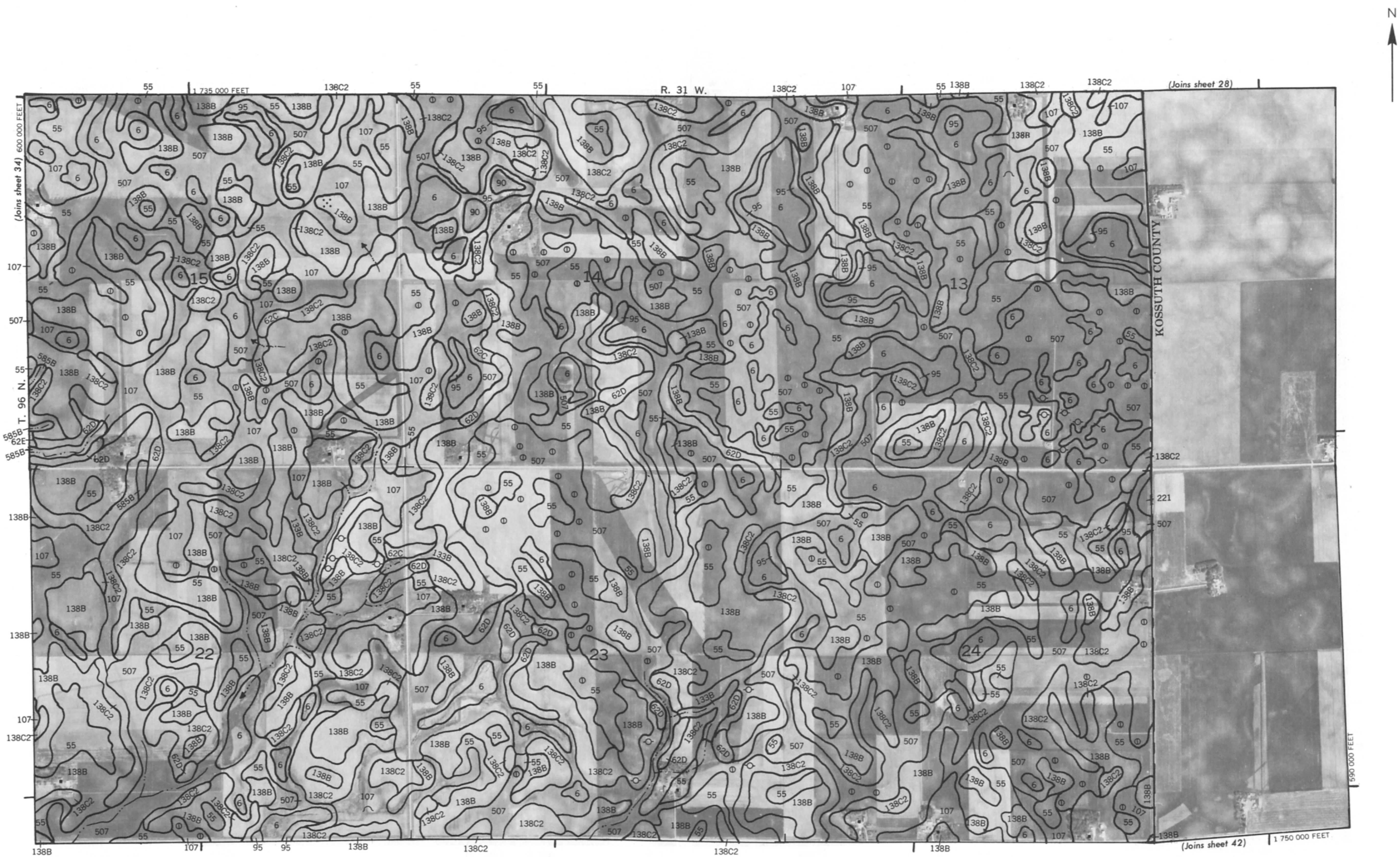



N
R. 33 W.
T. 96 N.
(Joins sheet 24)
(Joins sheet 30)
(Joins sheet 32)
(Joins sheet 38)
1 660 000 FEET
1 675 000 FEET
600 000 FEET
590 000 FEET
DRAINAGE
DITCH
DES MOINES
RIVER
CHICAGO
MILWAUKEE
ST PAUL
AND
PACIFIC

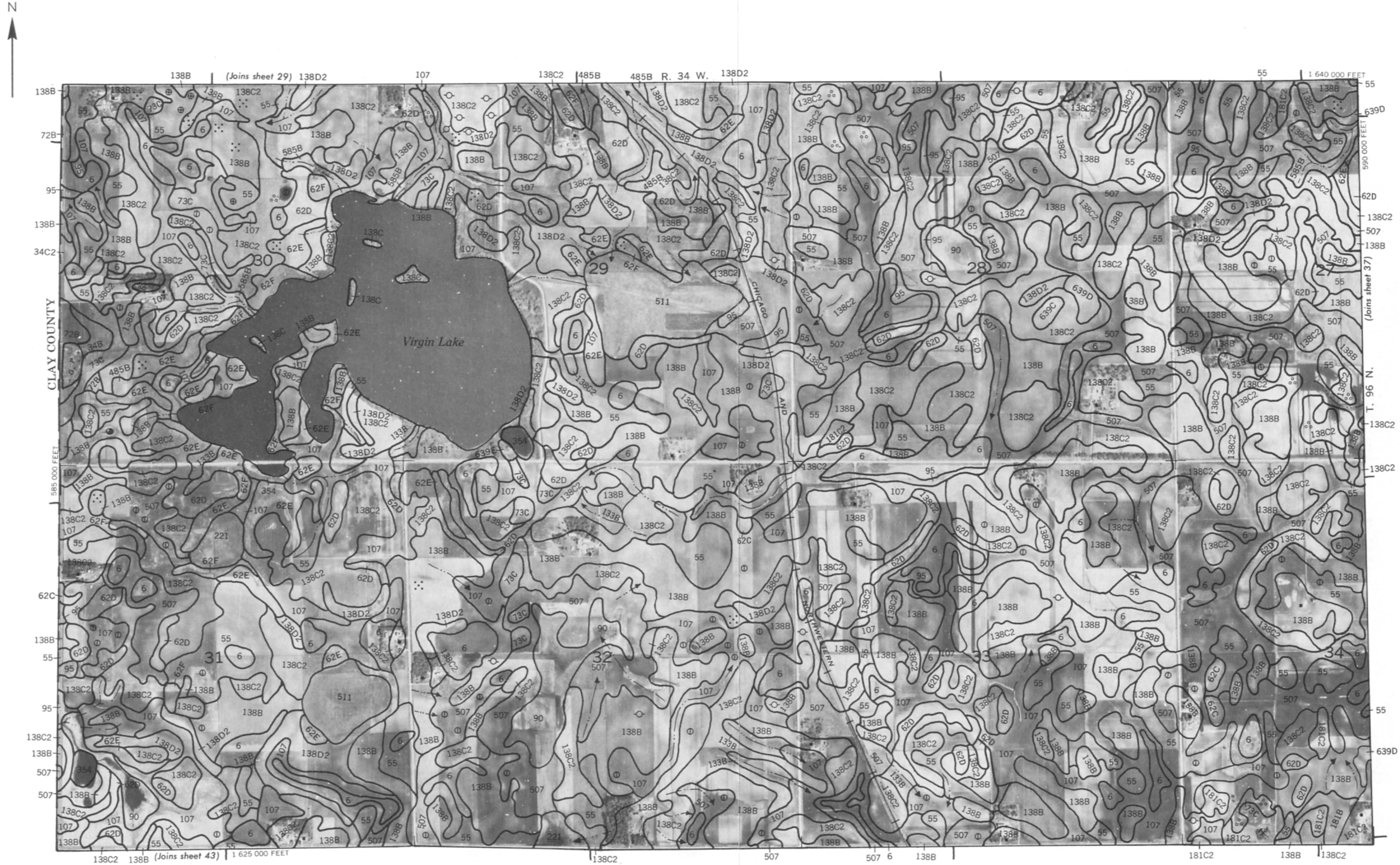

N
(Joins sheet 25)
R. 33 W.
R. 32 W.
1 695 000 FEET
600 000 FEET
(Joins sheet 33)
T. 96 N.
(Joins sheet 31)
(Joins sheet 39)
1 680 000 FEET
590 000 FEET
FIVE ISLAND LAKE
EMMETSBURG
DES MOINES RIVER
CHICAGO ROCK ISLAND AND PACIFIC
DRAINAGE DITCH 80
MADE LAND
G. P.
13
14
17
19
20
23
24

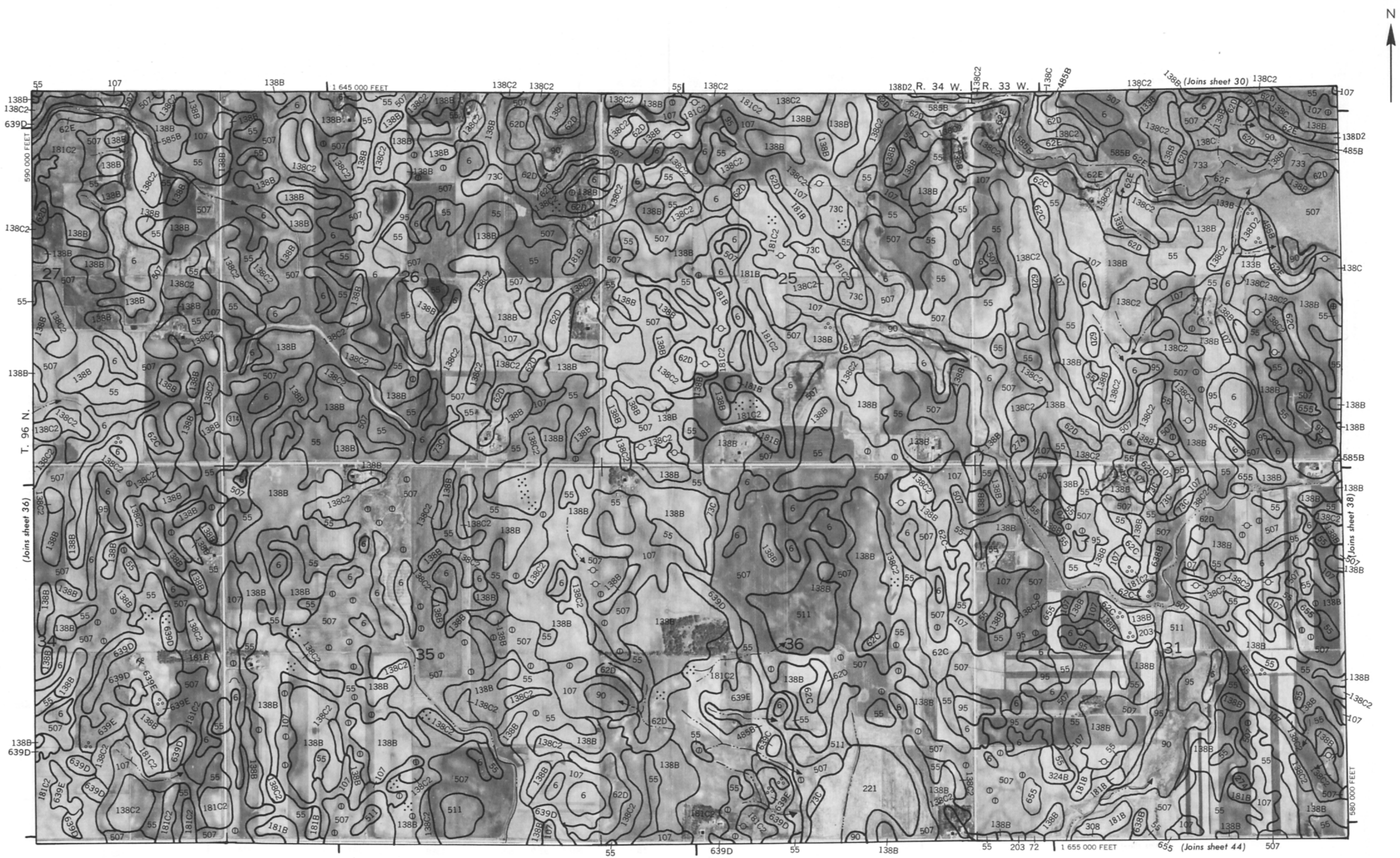

33
N
R. 32 W.
1 700 000 FEET
1 710 000 FEET
600 000 FEET
590 000 FEET
T. 96 N.
(Joins sheet 26)
(Joins sheet 32)
(Joins sheet 34)
(Joins sheet 40)
16
15
14
13
21
22
23
24
DRAINAGE
DITCH
LATERAL


34
N
(Joins sheet 27)
R. 32 W.
R. 31 W.
(Joins sheet 33)
(Joins sheet 35)
(Joins sheet 41)
1 730 000 FEET
1 715 000 FEET
590 000 FEET
595 000 FEET
T. 96 N.
Sportsmans Park
water
GRAVEL PIT
Creek
Prairie
Cylinder
13
17
16
18
24
19
20
21

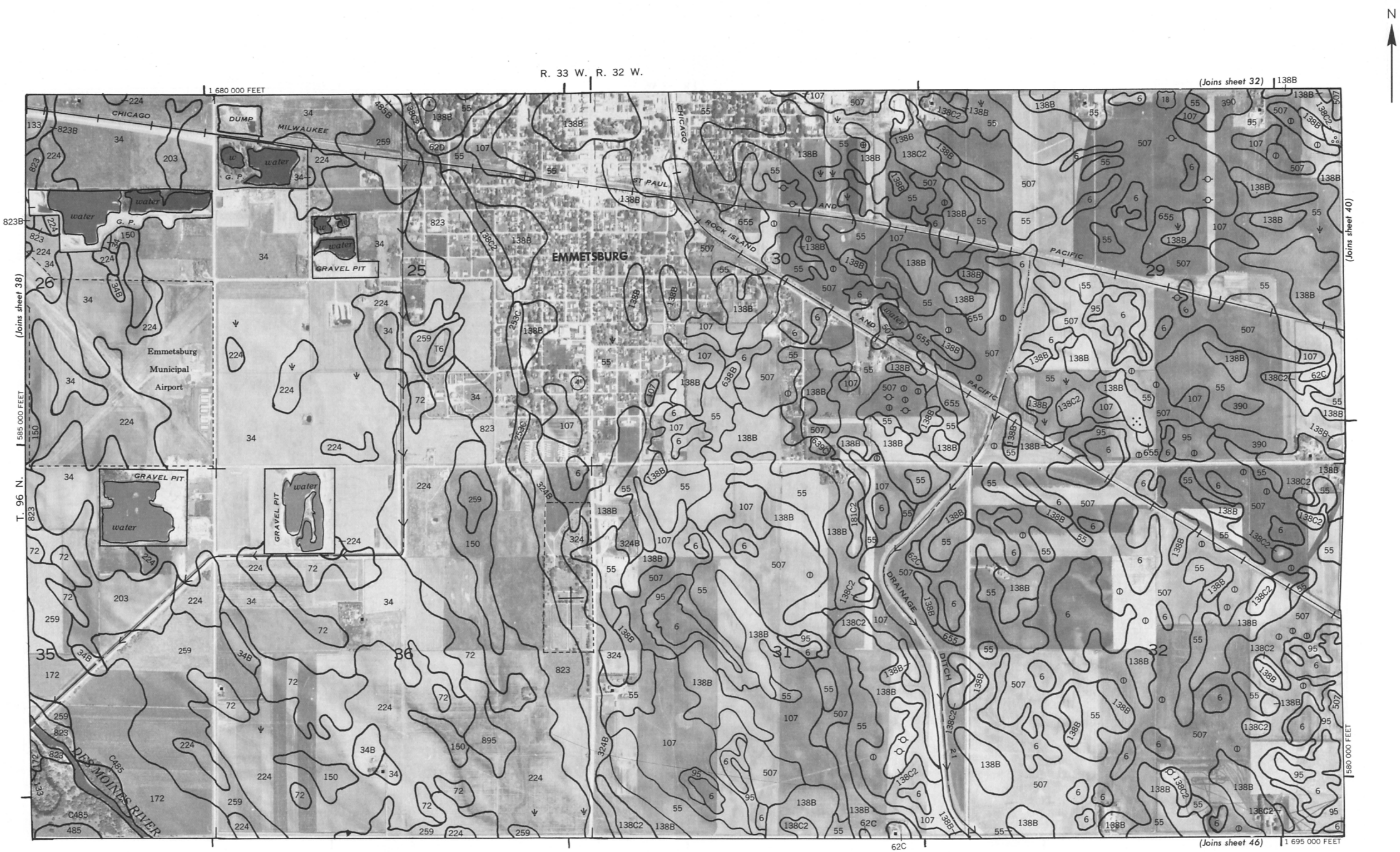

N
R. 31 W.
T. 96 N.
(Joins sheet 34)
(Joins sheet 28)
(Joins sheet 42)
KOSSUTH COUNTY
1 735 000 FEET
600 000 FEET
1 750 000 FEET
590 000 FEET
15
14
13
22
23
24

PALO ALTO COUNTY, IOWA — SHEET NUMBER 36

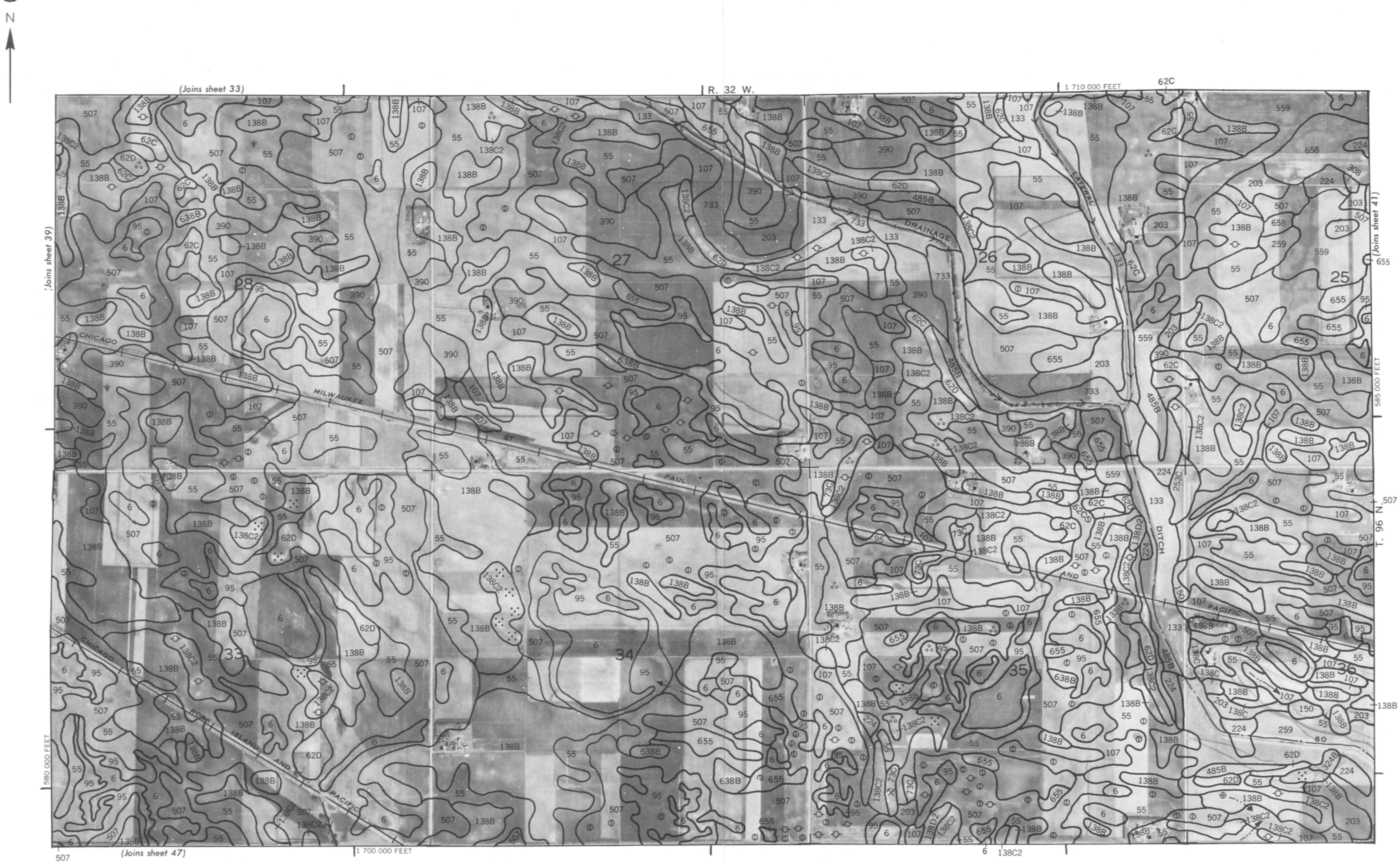



N
1 645 000 FEET
R. 34 W.
R. 33 W.
(Joins sheet 30)
590 000 FEET
T. 96 N.
(Joins sheet 36)
(Joins sheet 38)
580 000 FEET
1 655 000 FEET
(Joins sheet 44)
27
26
25
30
34
35
36
31

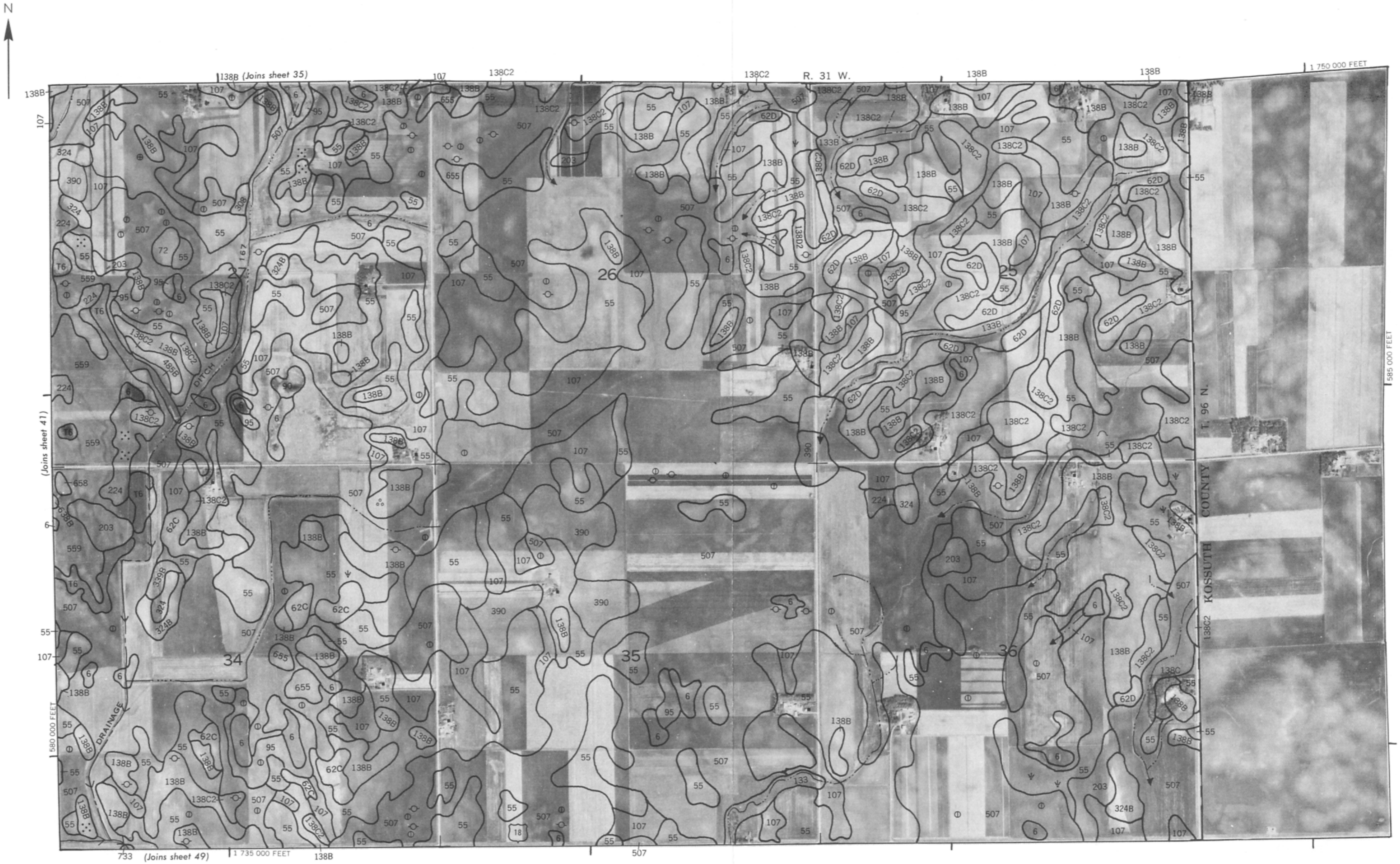

N
(Joins sheet 31)
R. 33 W.
1 675 000 FEET
C M ST P AND P
Emmetsburg Municipal Airport
(Joins sheet 37)
T. 96 N.
(Joins sheet 39)
585 000 FEET
580 000 FEET
1 660 000 FEET
(Joins sheet 45)
DES MOINES RIVER
Silver
Creek
29
28
27
26
32
33
34
35


N
R. 33 W.
R. 32 W.
1 680 000 FEET
(Joins sheet 32)
(Joins sheet 38)
(Joins sheet 40)
(Joins sheet 46)
1 695 000 FEET
585 000 FEET
580 000 FEET
T. 96 N.
EMMETSBURG
Emmetsburg
Municipal
Airport
CHICAGO
MILWAUKEE
ST PAUL
AND
PACIFIC
CHICAGO
ROCK ISLAND
AND
PACIFIC
DUMP
GRAVEL PIT
G. P.
water
DRAINAGE
DITCH
21
DES MOINES RIVER
25
26
29
30
31
32
35
36

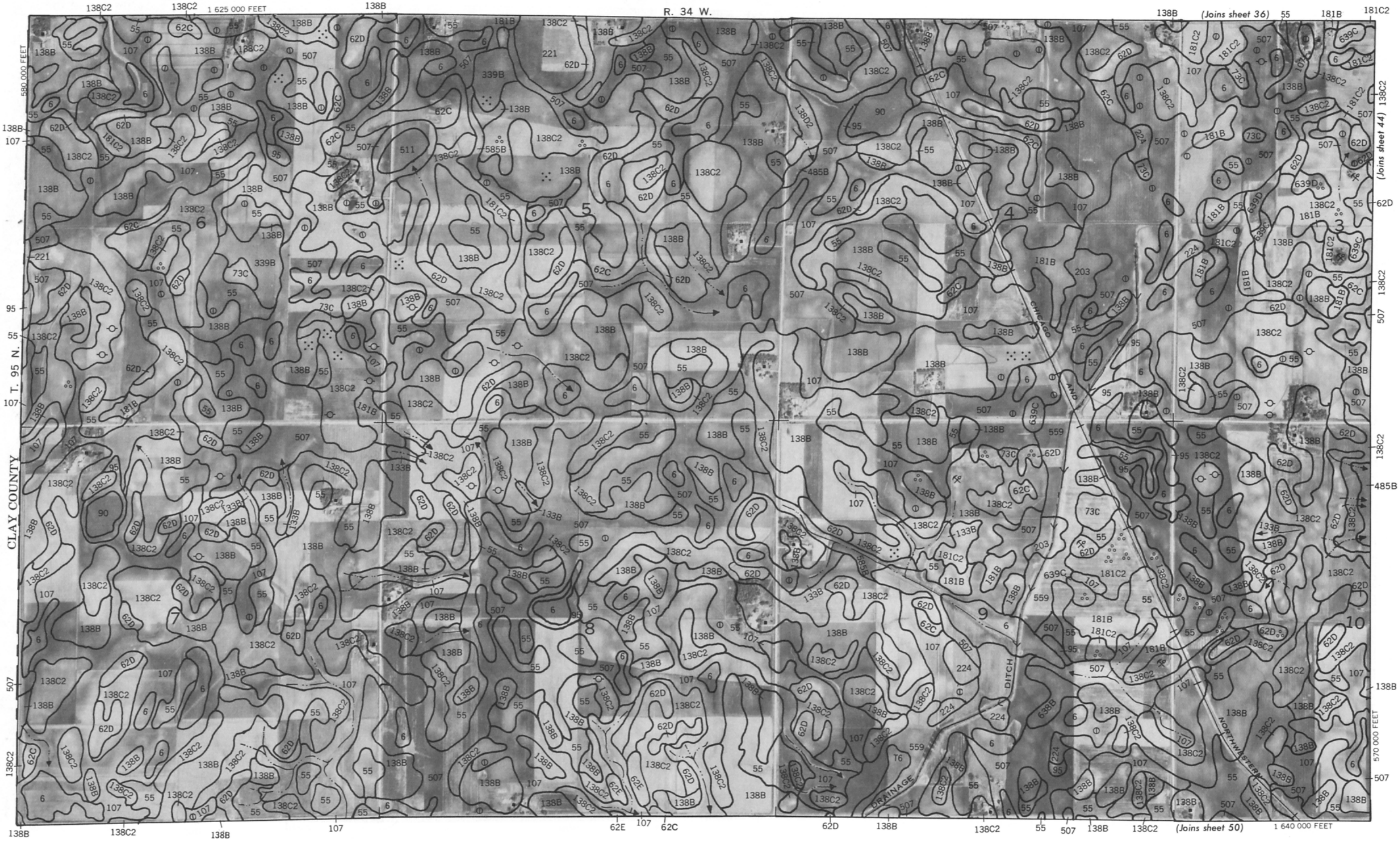
PALO ALTO COUNTY, IOWA — SHEET NUMBER 40




N
1 715 000 FEET
R. 32 W.
R. 31 W.
(Joins sheet 34)
(Joins sheet 42)
(Joins sheet 40)
(Joins sheet 48)
1 730 000 FEET
585 000 FEET
580 000 FEET
T. 96 N.
25
30
29
28
36
31
32
33
Cylinder
Creek
Cylinder Creek
Prairie Creek
CHICAGO
MILWAUKEE
ST PAUL
AND
PACIFIC
DRAINAGE DITCH 80
18

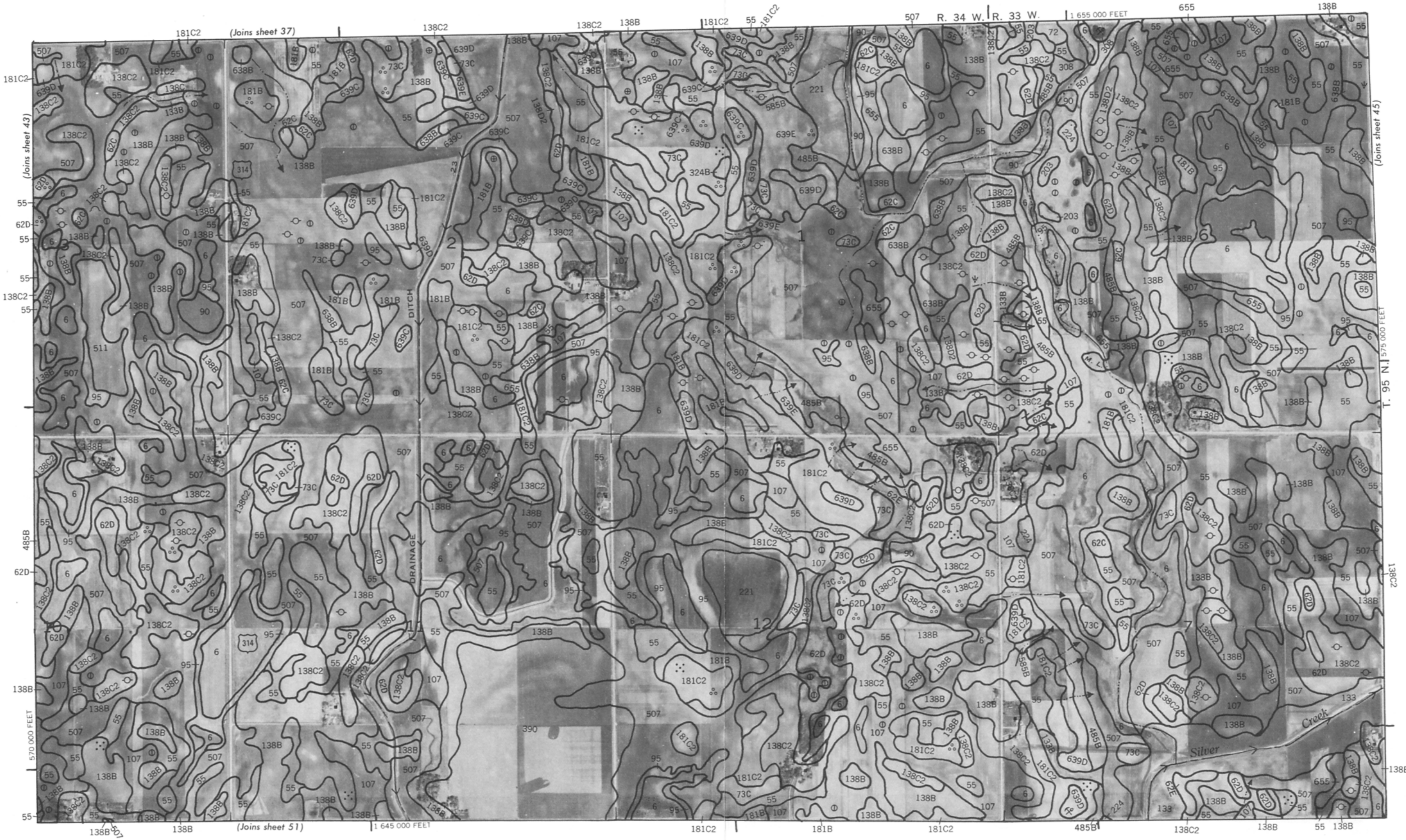

N
138B (Joins sheet 35)
R. 31 W.
1 750 000 FEET
(Joins sheet 41)
585 000 FEET
580 000 FEET
T. 96 N.
KOSSUTH COUNTY
DITCH
DRAINAGE
733 (Joins sheet 49)
1 735 000 FEET
26
25
27
34
35
36

N

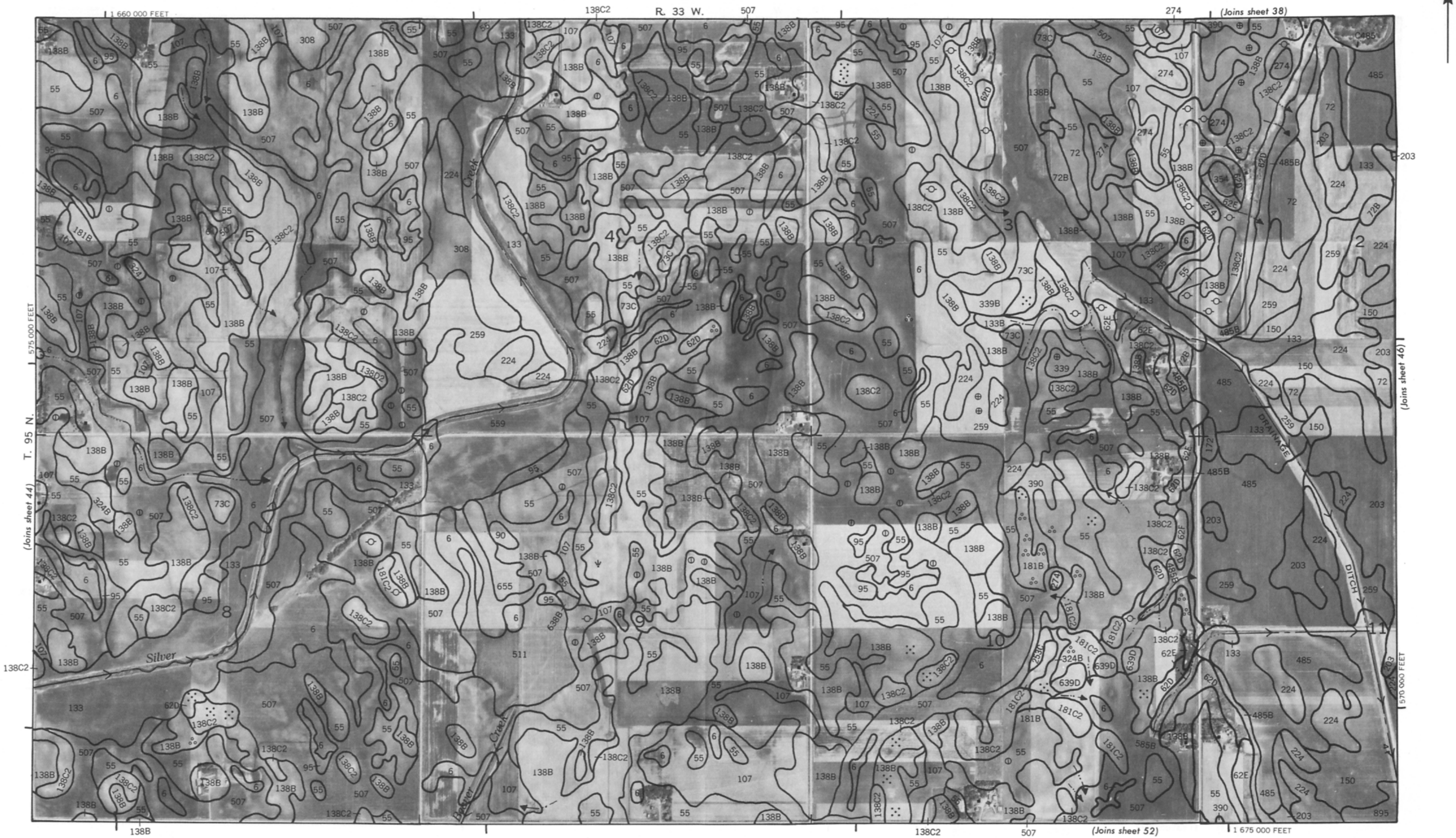

R. 34 W.
T. 95 N.
CLAY COUNTY
(Joins sheet 36)
(Joins sheet 44)
(Joins sheet 50)
1 625 000 FEET
1 640 000 FEET
580 000 FEET
570 000 FEET
CHICAGO AND NORTHWESTERN
DRAINAGE DITCH

44

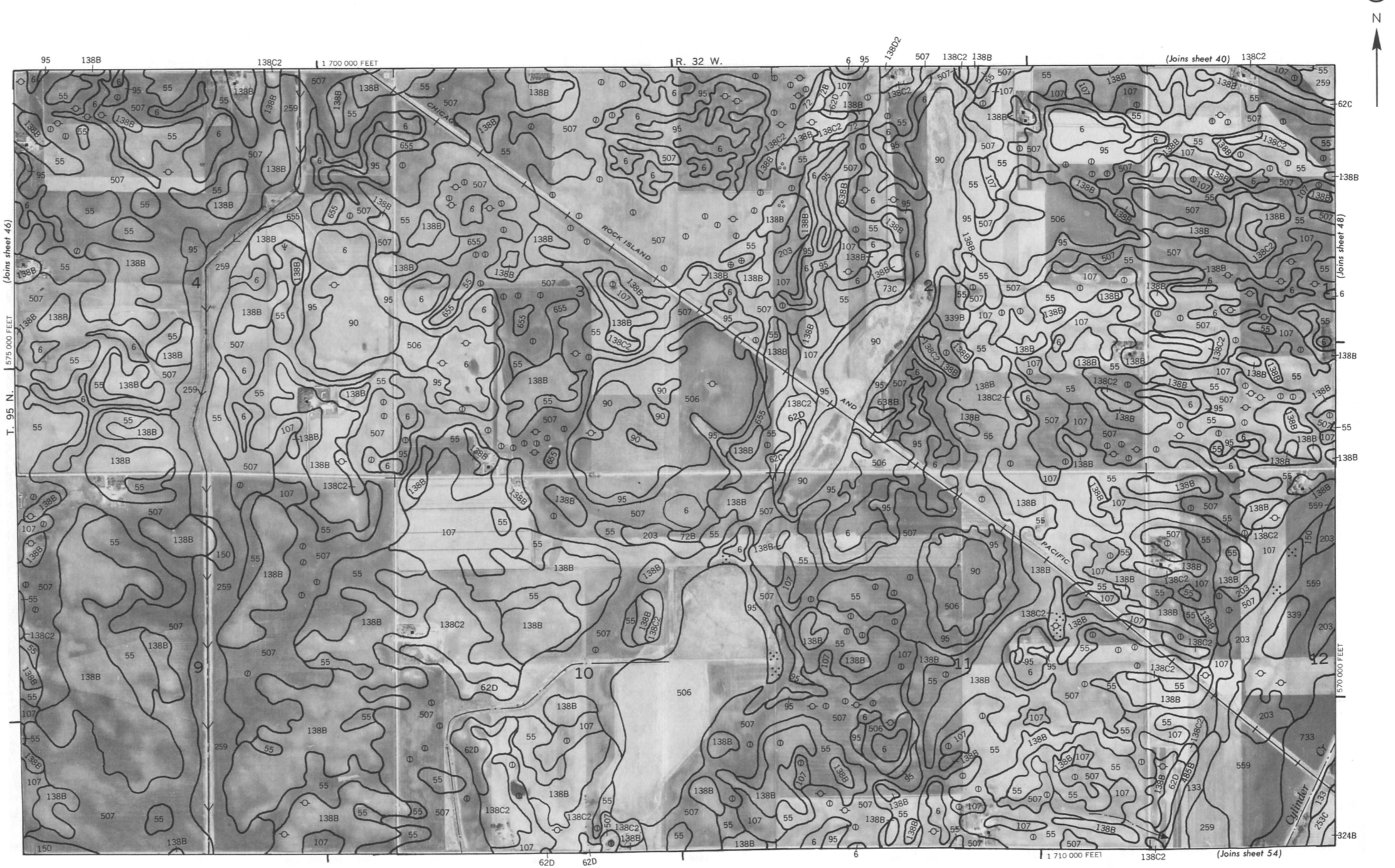
N


(Joins sheet 37)
(Joins sheet 43)
(Joins sheet 45)
(Joins sheet 51)
R. 34 W.
R. 33 W.
1 655 000 FEET
1 645 000 FEET
575 000 FEET
570 000 FEET
T. 95 N.
DRAINAGE
DITCH
Silver
Creek

PALO ALTO COUNTY, IOWA — SHEET NUMBER 45



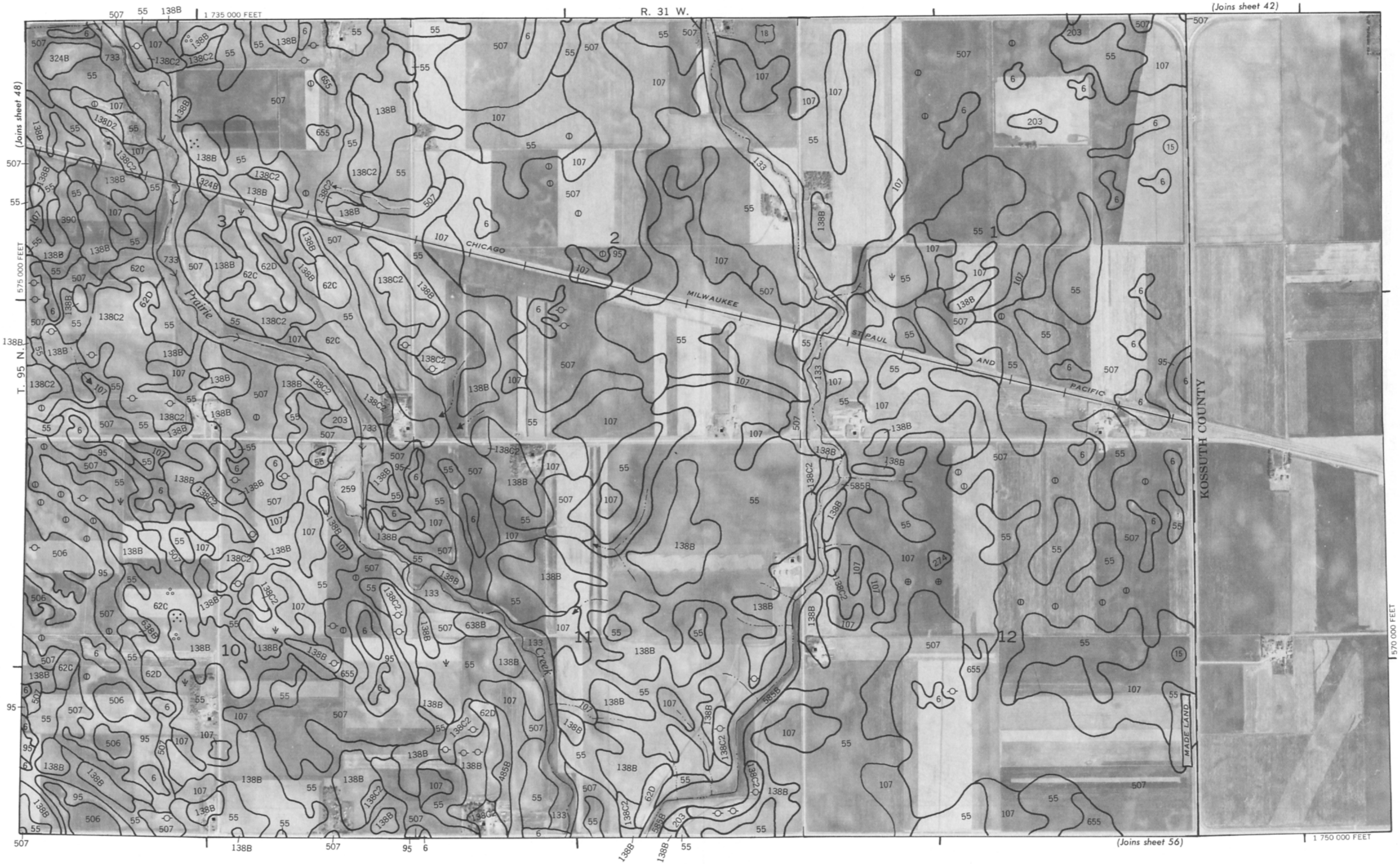

46
N
(Joins sheet 39)
R. 33 W.
R. 32 W.
1 695 000 FEET
(Joins sheet 45)
(Joins sheet 47)
575 000 FEET
T. 95 N.
570 000 FEET
(Joins sheet 53)
1 680 000 FEET
DES MOINES
RIVER
DRAINAGE
DITCH
water


47
N
R. 32 W.
T. 95 N.
1 700 000 FEET
1 710 000 FEET
575 000 FEET
570 000 FEET
(Joins sheet 40)
(Joins sheet 46)
(Joins sheet 48)
(Joins sheet 54)
CHICAGO
ROCK ISLAND
AND
PACIFIC
Cylinder Cr.


N
R. 32 W.
R. 31 W. (Joins sheet 41)
1 730 000 FEET
CHICAGO
MILWAUKEE
ST PAUL
AND
PACIFIC
DRAINAGE
DITCH
Creek
LATERAL
Cylinder
(Joins sheet 47)
(Joins sheet 49)
T. 95 N.
575 000 FEET
570 000 FEET
1 715 000 FEET
(Joins sheet 55)

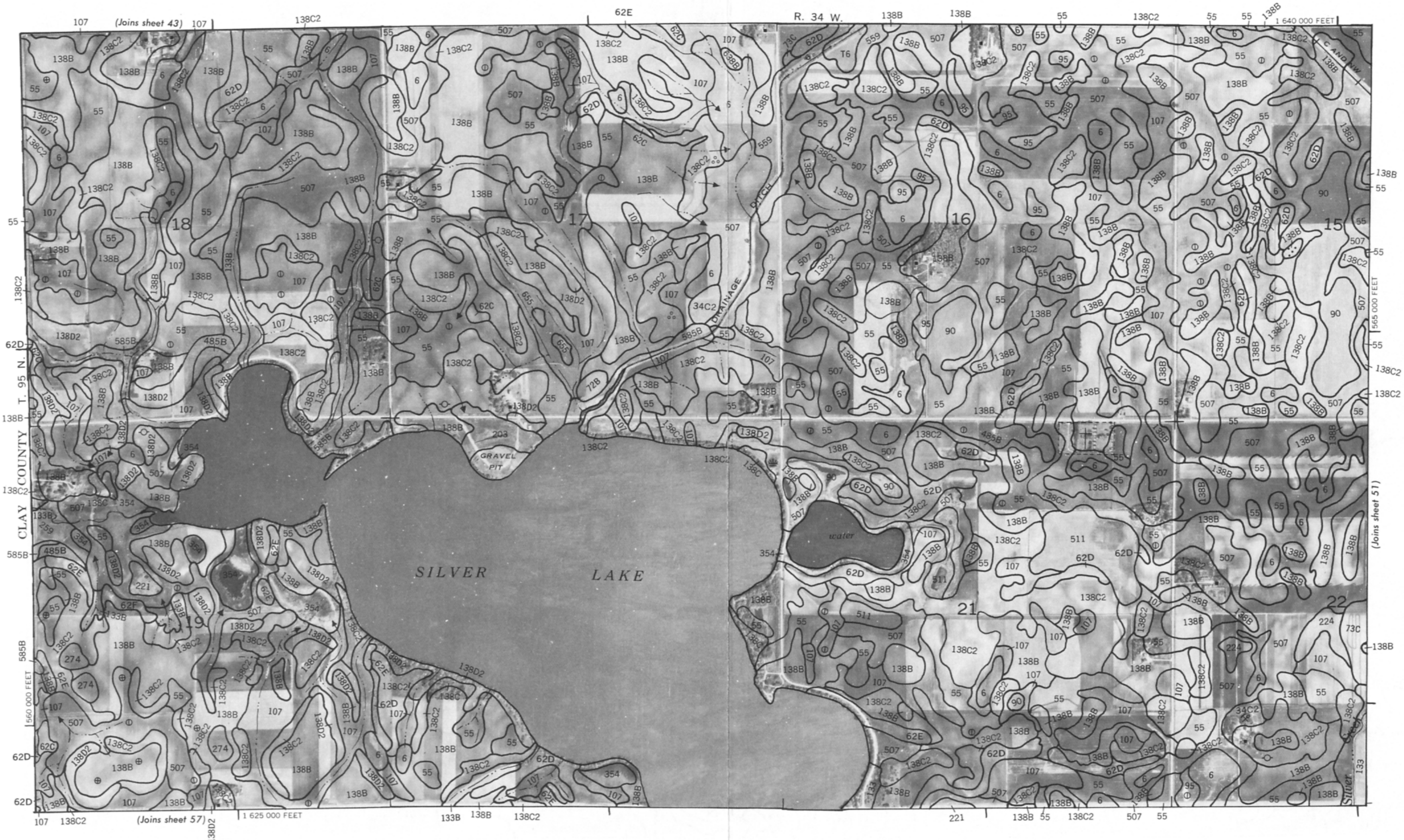
49

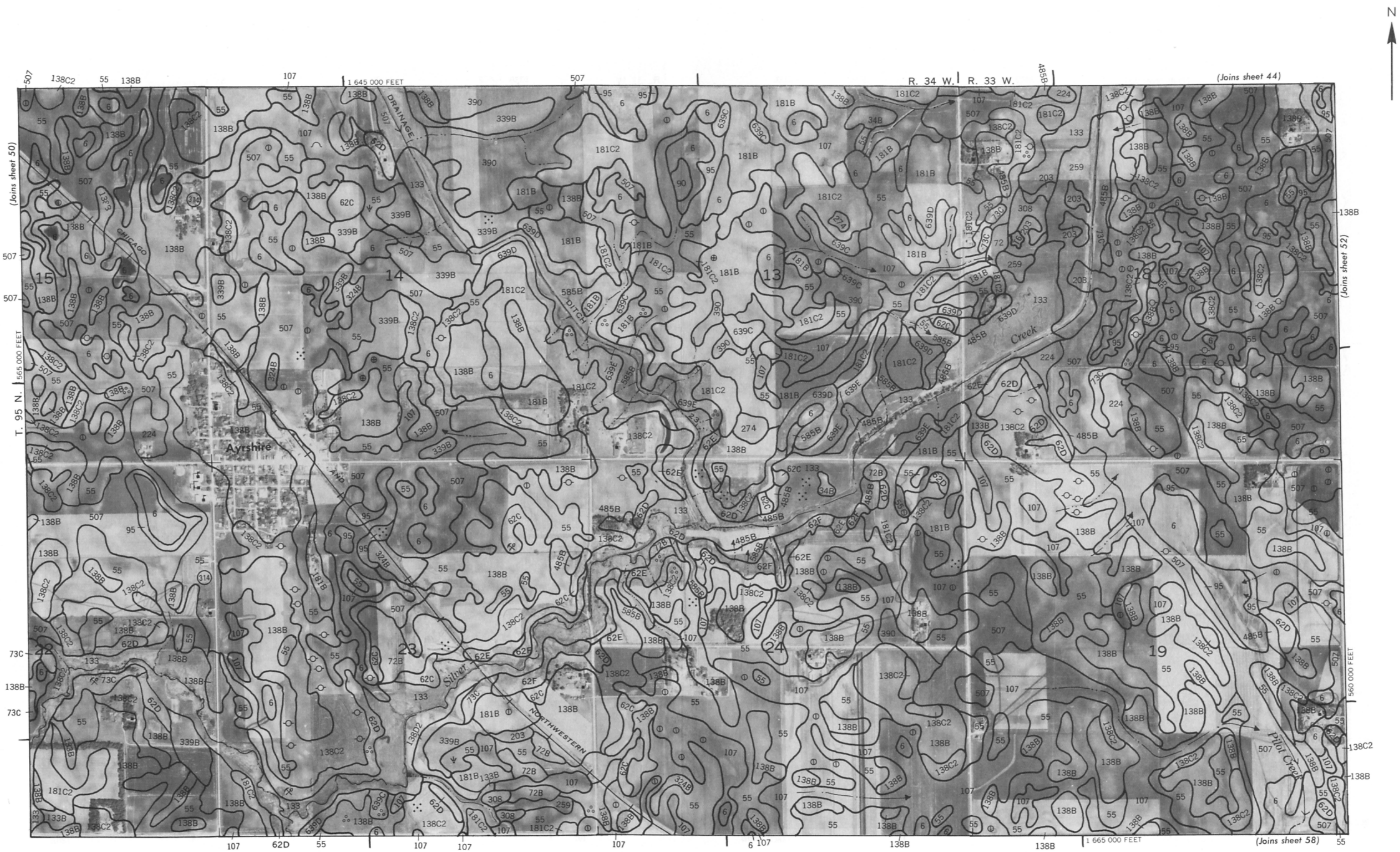
N



R. 31 W.
T. 95 N.
(Joins sheet 42)
(Joins sheet 48)
(Joins sheet 56)
1 735 000 FEET
1 750 000 FEET
575 000 FEET
570 000 FEET
CHICAGO
MILWAUKEE
ST PAUL
AND
PACIFIC
Prairie
Creek
KOSSUTH COUNTY
MADE LAND
18
1
2
3
10
11
12

N


(Joins sheet 43)
(Joins sheet 57)
(Joins sheet 51)
R. 34 W.
T. 95 N.
CLAY COUNTY
SILVER LAKE
GRAVEL PIT
DRAINAGE DITCH
water
1 640 000 FEET
1 625 000 FEET
565 000 FEET
560 000 FEET
15
16
17
18
19
21
22

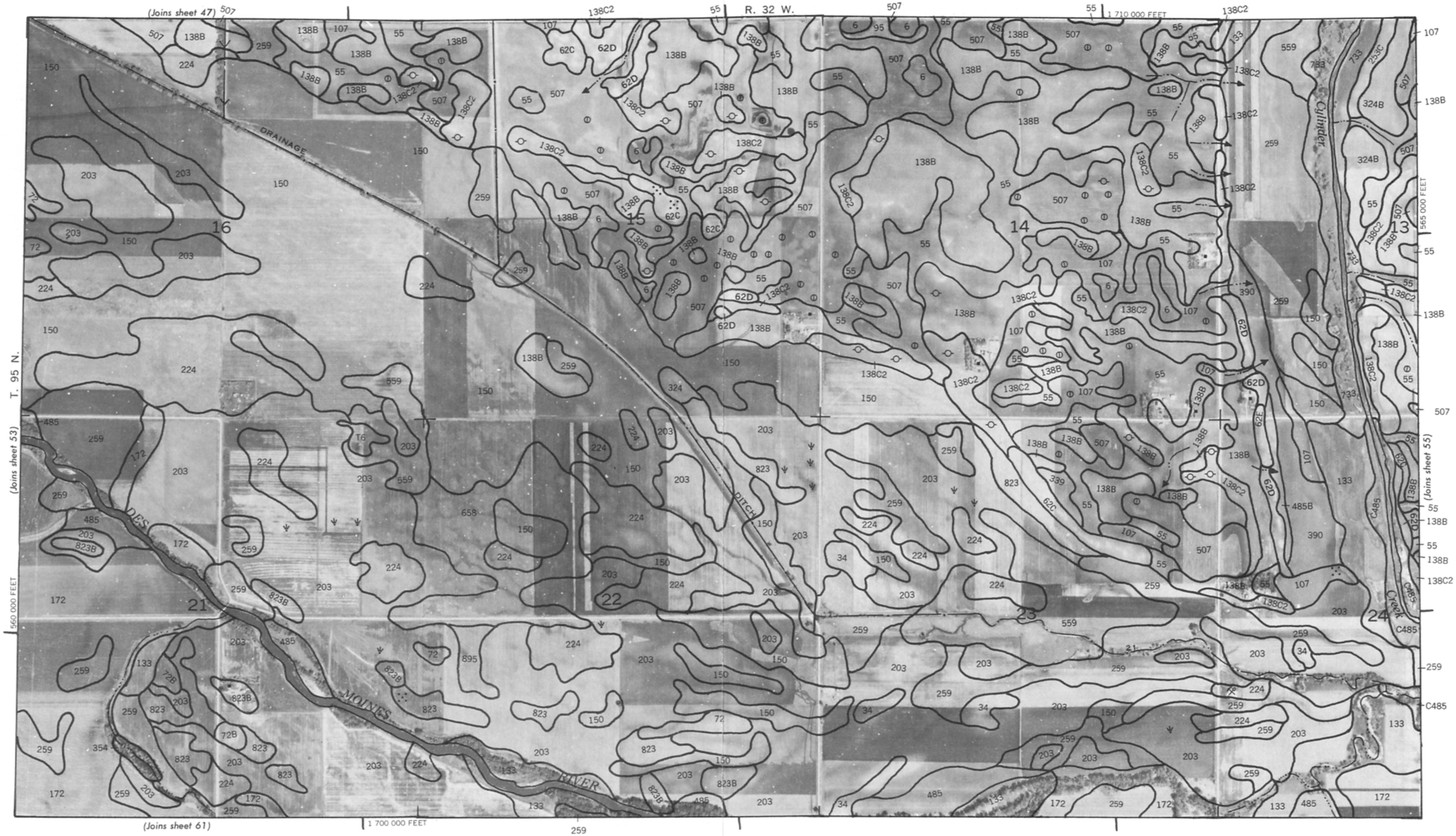

N
1 645 000 FEET
R. 34 W.
R. 33 W.
(Joins sheet 44)
(Joins sheet 50)
(Joins sheet 52)
(Joins sheet 58)
565 000 FEET
560 000 FEET
1 665 000 FEET
T. 95 N.
Ayrshire
CHICAGO AND NORTHWESTERN
DRAINAGE DITCH
Creek
Silver
Pilot Creek
15
14
13
18
22
23
24
19


52
N
(Joins sheet 45)
R. 33 W.
1 675 000 FEET
T. 95 N.
(Joins sheet 51)
(Joins sheet 53)
(Joins sheet 59)
1 660 000 FEET
560 000 FEET
565 000 FEET
Beaver
Creek

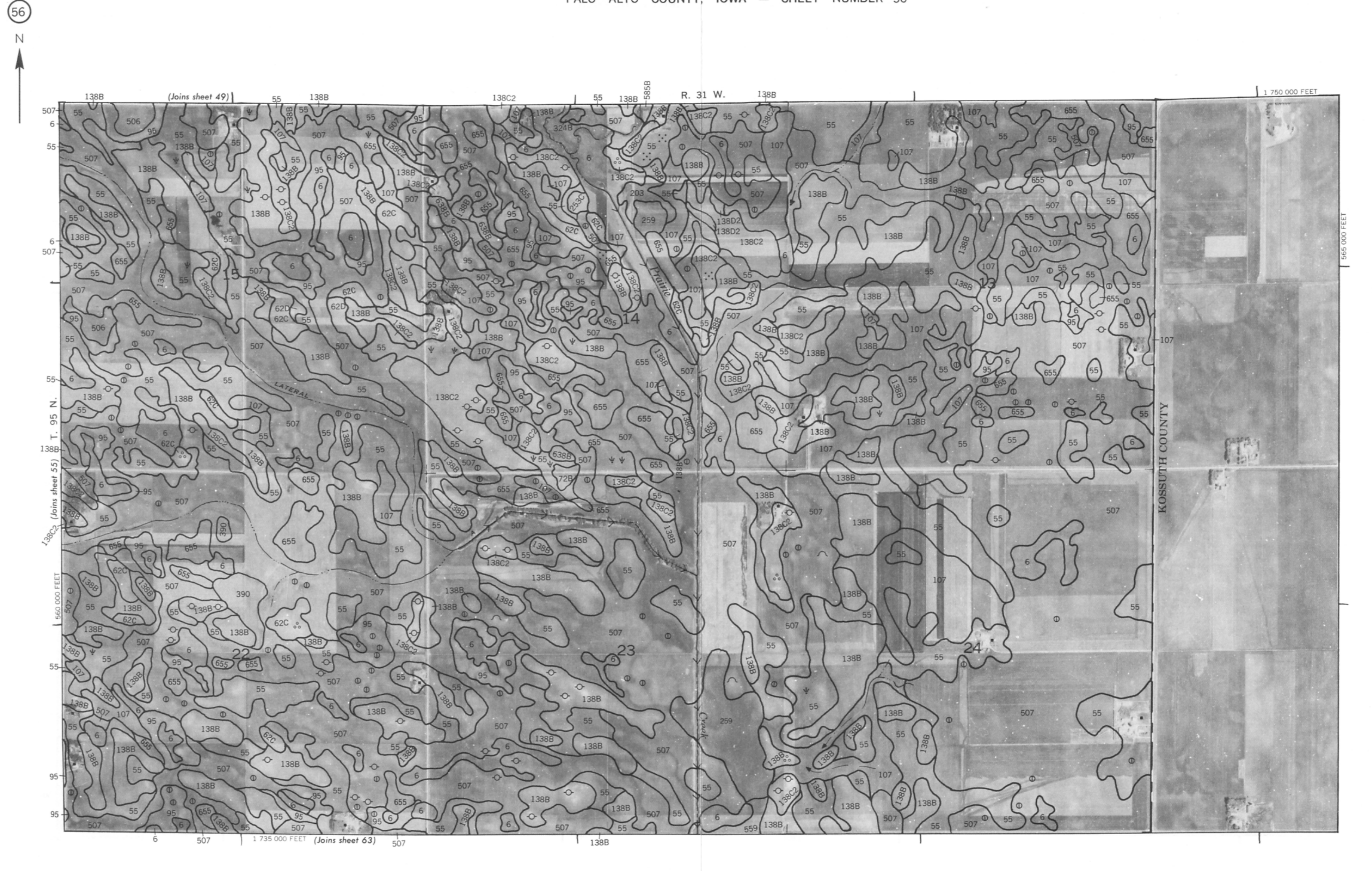
N

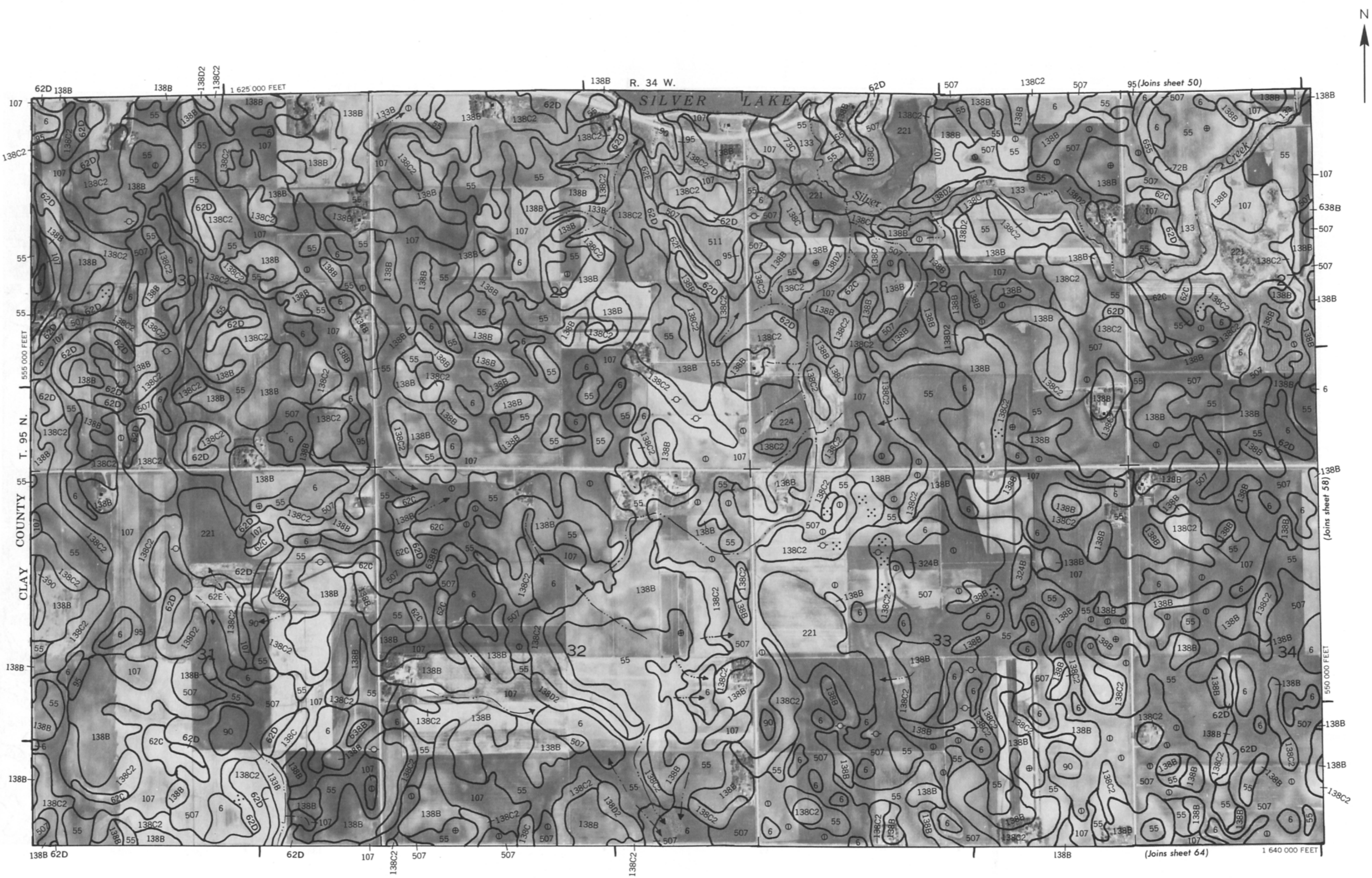

(Joins sheet 46)
(Joins sheet 52)
(Joins sheet 54)
(Joins sheet 60)
R. 33 W.
R. 32 W.
T. 95 N.
1 680 000 FEET
1 695 000 FEET
565 000 FEET
560 000 FEET
DRAINAGE
DITCH
DES
MOINES
RIVER
G. P.
14
13
18
17
23
24
19
20

N


(Joins sheet 47)
R. 32 W.
1 710 000 FEET
T. 95 N.
(Joins sheet 53)
(Joins sheet 55)
565 000 FEET
560 000 FEET
(Joins sheet 61)
1 700 000 FEET
DRAINAGE
DITCH
DES
MOINES
RIVER
Cylinder
Creek
16
15
14
13
21
22
23
24

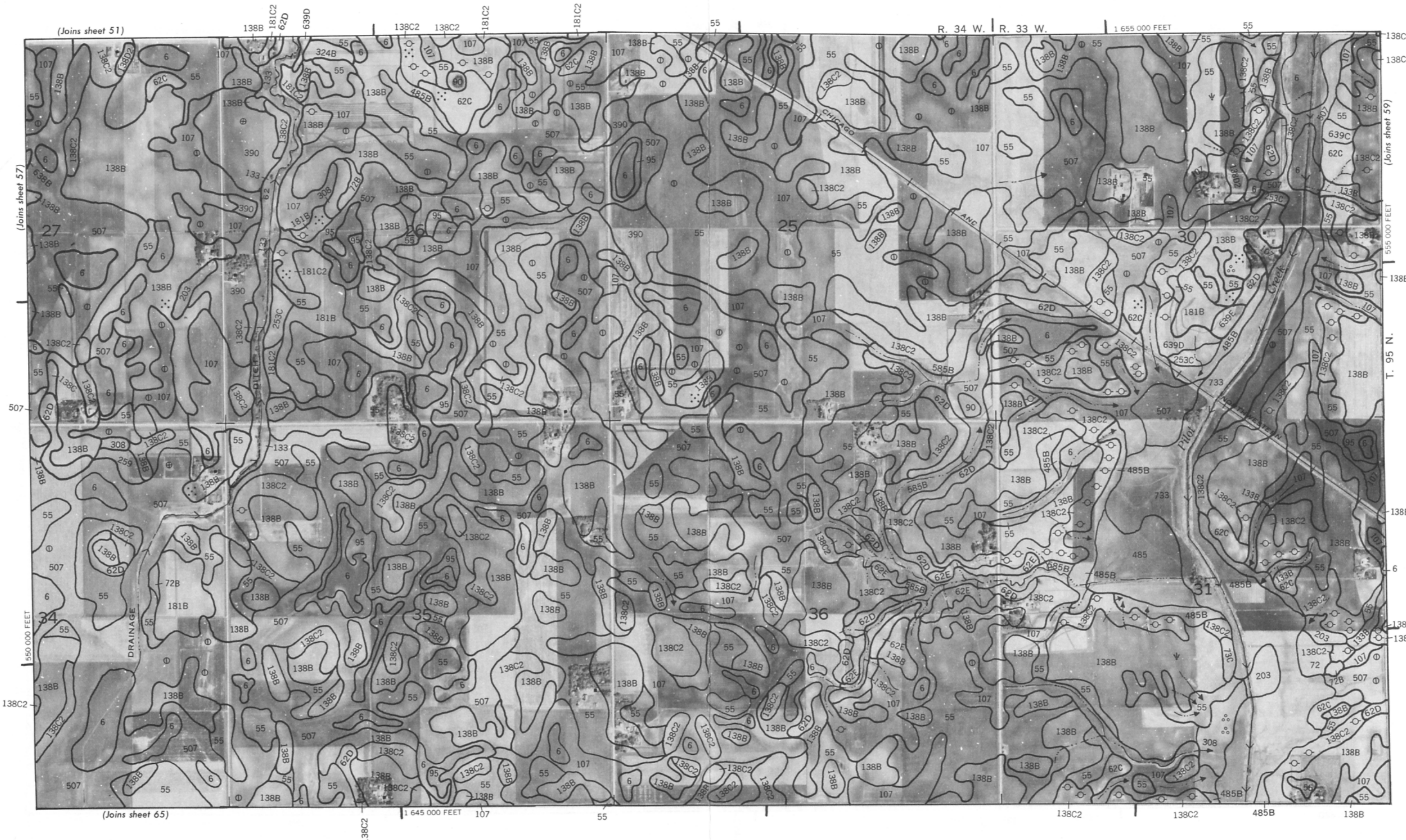

N
1 715 000 FEET
R. 32 W.
R. 31 W.
(Joins sheet 48)
(Joins sheet 54)
(Joins sheet 56)
(Joins sheet 62)
565 000 FEET
560 000 FEET
1 730 000 FEET
T. 95 N.
CHICAGO
ROCK
ISLAND
AND
PACIFIC
LATERAL A
Cylinder
Creek
Rodman
13
18
17
16
24
19
20
21


56
N
(Joins sheet 49)
R. 31 W.
1 750 000 FEET
565 000 FEET
T. 95 N.
(Joins sheet 55)
560 000 FEET
1 735 000 FEET
(Joins sheet 63)
KOSSUTH COUNTY
LATERAL
Prairie
Creek
13
14
15
22
23
24

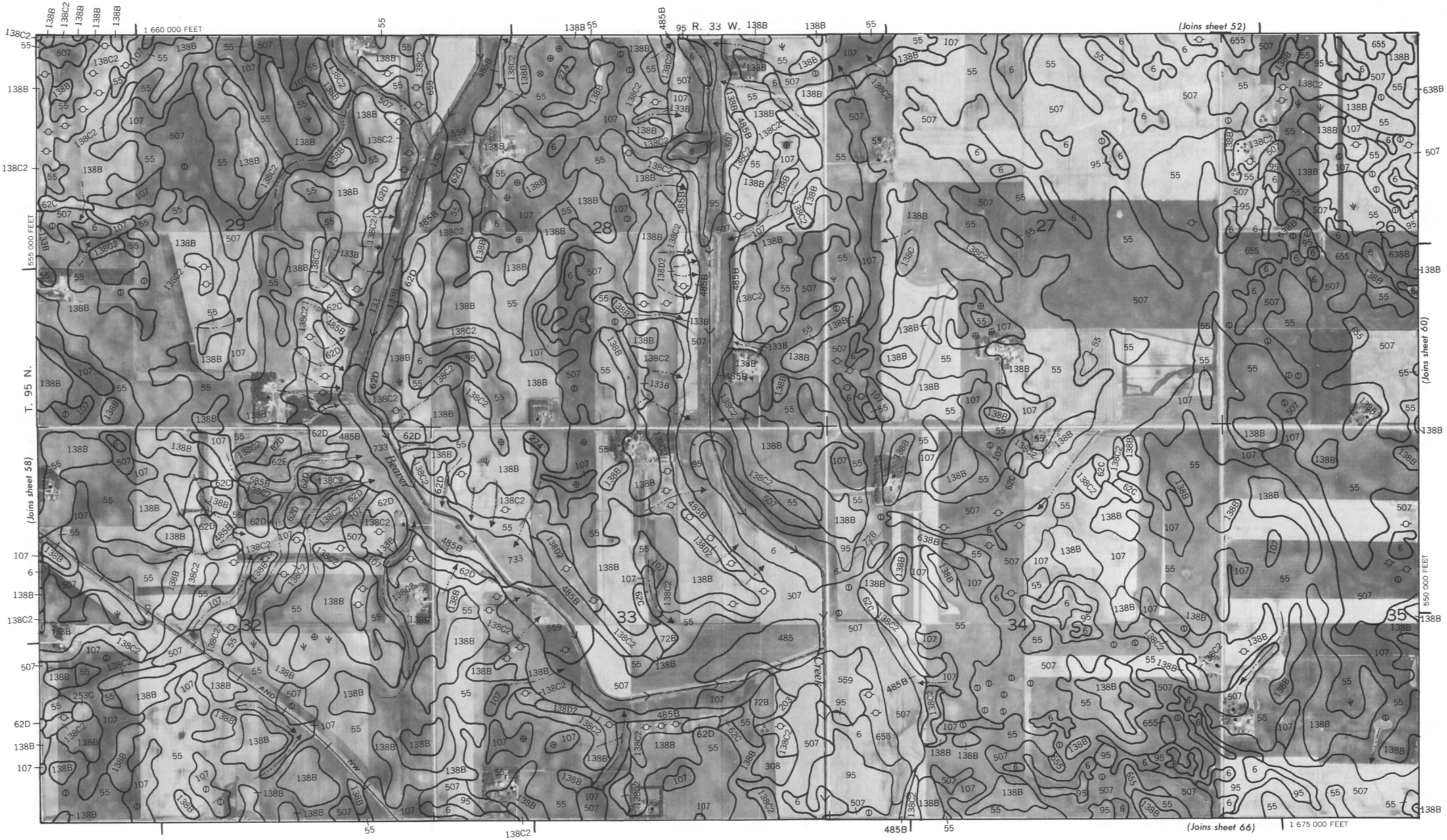

N
R. 34 W.
SILVER LAKE
1 625 000 FEET
(Joins sheet 50)
T. 95 N.
CLAY COUNTY
555 000 FEET
550 000 FEET
(Joins sheet 58)
(Joins sheet 64)
1 640 000 FEET
Silver
Creek

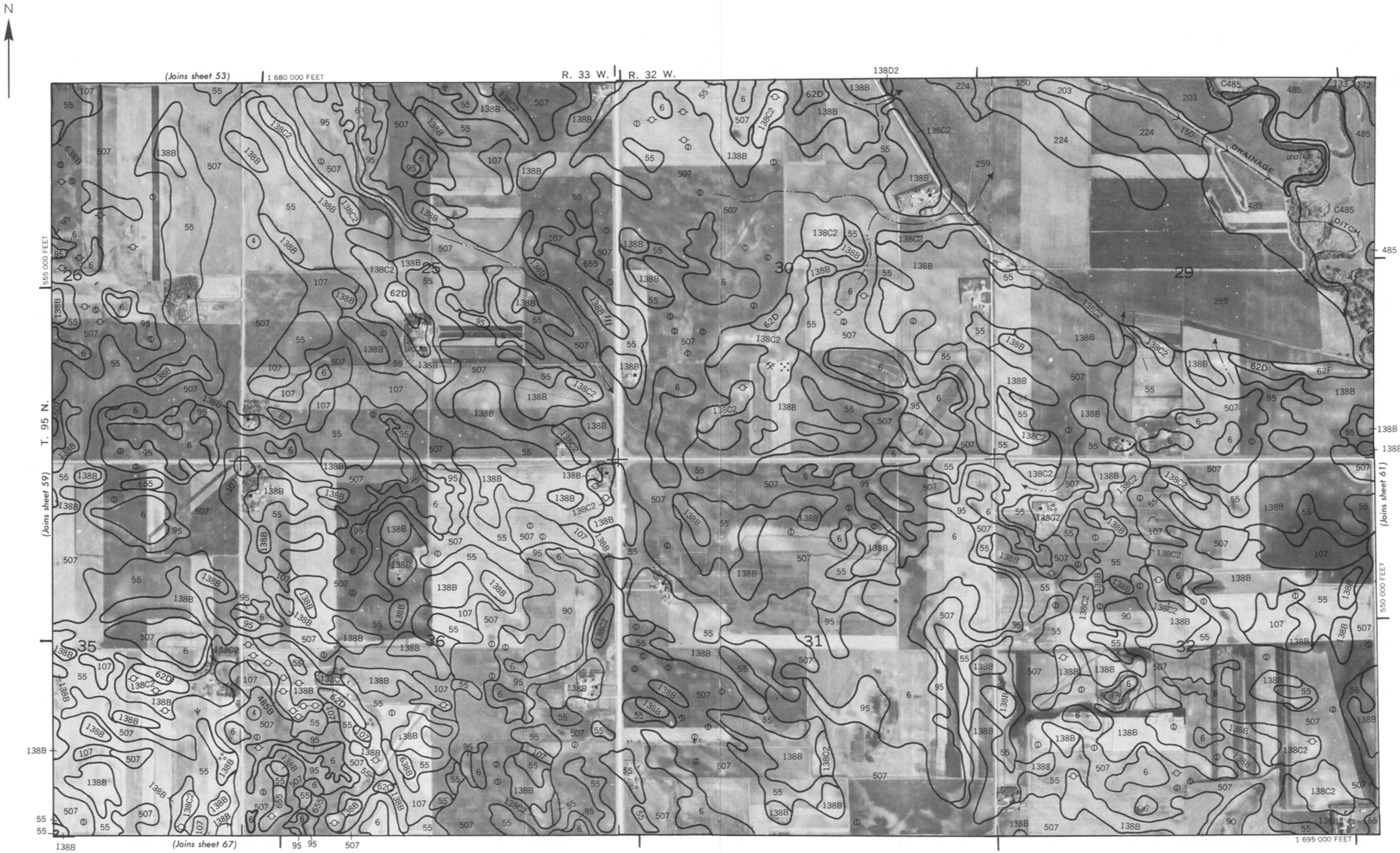
58

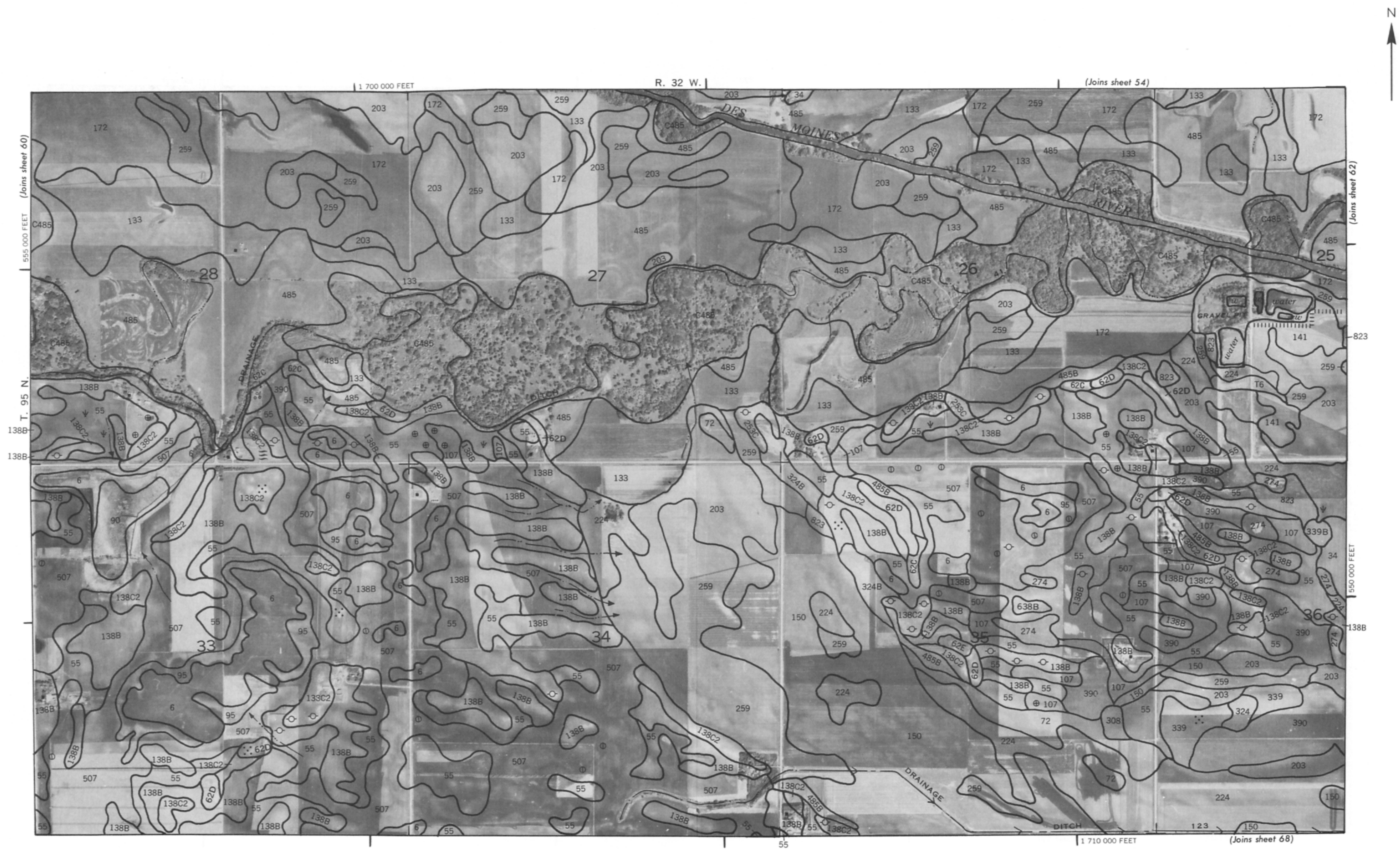
N


(Joins sheet 51)
R. 34 W.
R. 33 W.
1 655 000 FEET
(Joins sheet 57)
(Joins sheet 59)
555 000 FEET
T. 95 N.
550 000 FEET
1 645 000 FEET
(Joins sheet 65)
CHICAGO
DITCH
DRAINAGE
Pilot
Creek
27
26
25
30
34
35
36
31

N

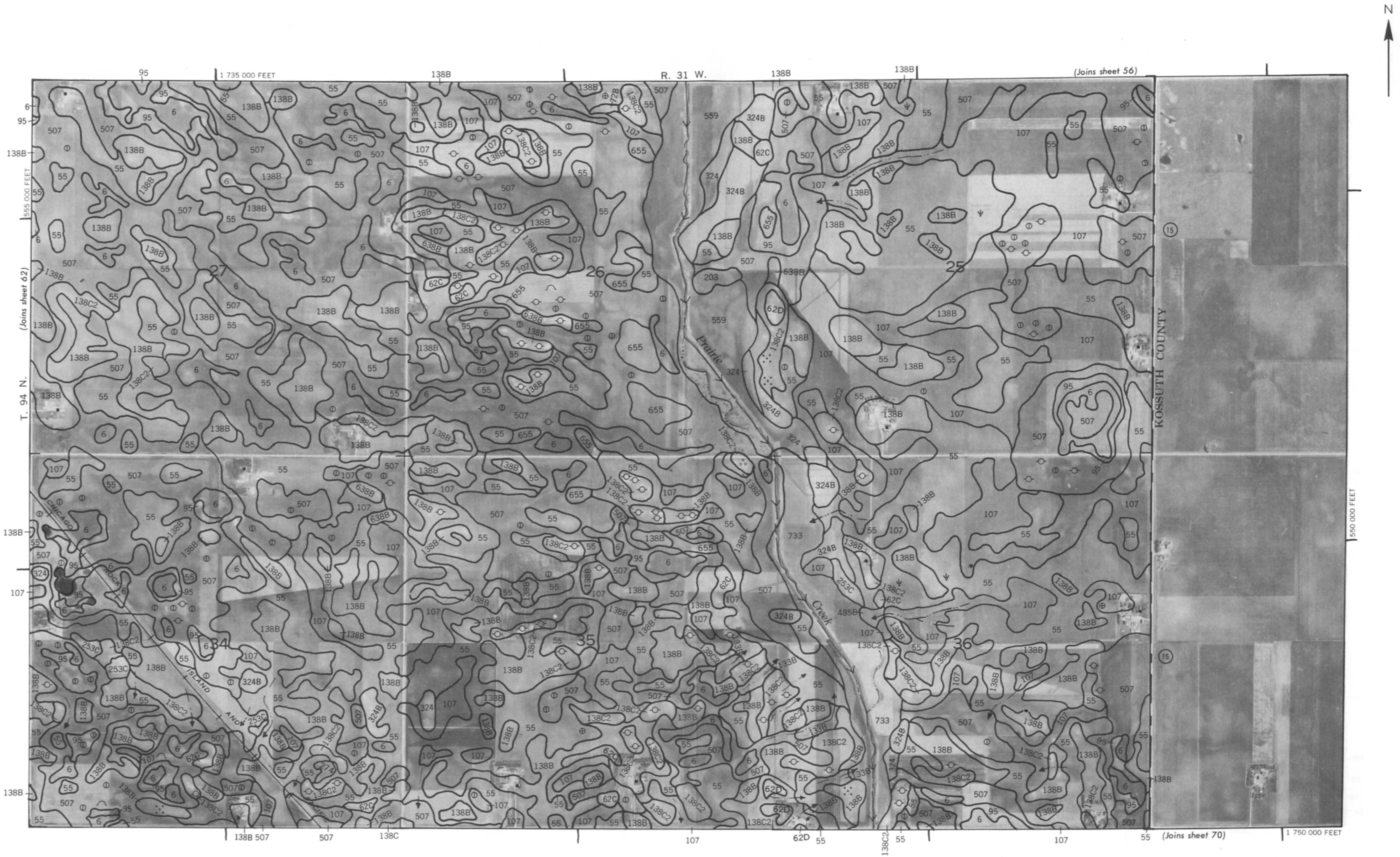

1 660 000 FEET
R. 33 W.
(Joins sheet 52)
555 000 FEET
T. 95 N.
(Joins sheet 58)
(Joins sheet 60)
550 000 FEET
(Joins sheet 66)
1 675 000 FEET
Beaver
Creek
29
28
27
26
32
33
34
35


N
(Joins sheet 53)
1 680 000 FEET
R. 33 W.
R. 32 W.
138D2
555 000 FEET
T. 95 N.
(Joins sheet 59)
(Joins sheet 61)
550 000 FEET
(Joins sheet 67)
1 695 000 FEET
26
25
30
29
35
36
31
32
DRAINAGE
DITCH
water
485
138B
138B
95
95
507
55
55
138B


N
(Joins sheet 54)
R. 32 W.
1 700 000 FEET
(Joins sheet 60)
555 000 FEET
T. 95 N.
(Joins sheet 62)
550 000 FEET
1 710 000 FEET
(Joins sheet 68)
DES MOINES RIVER
DRAINAGE DITCH
GRAVEL PIT
water
25
26
27
28
33
34
35
36

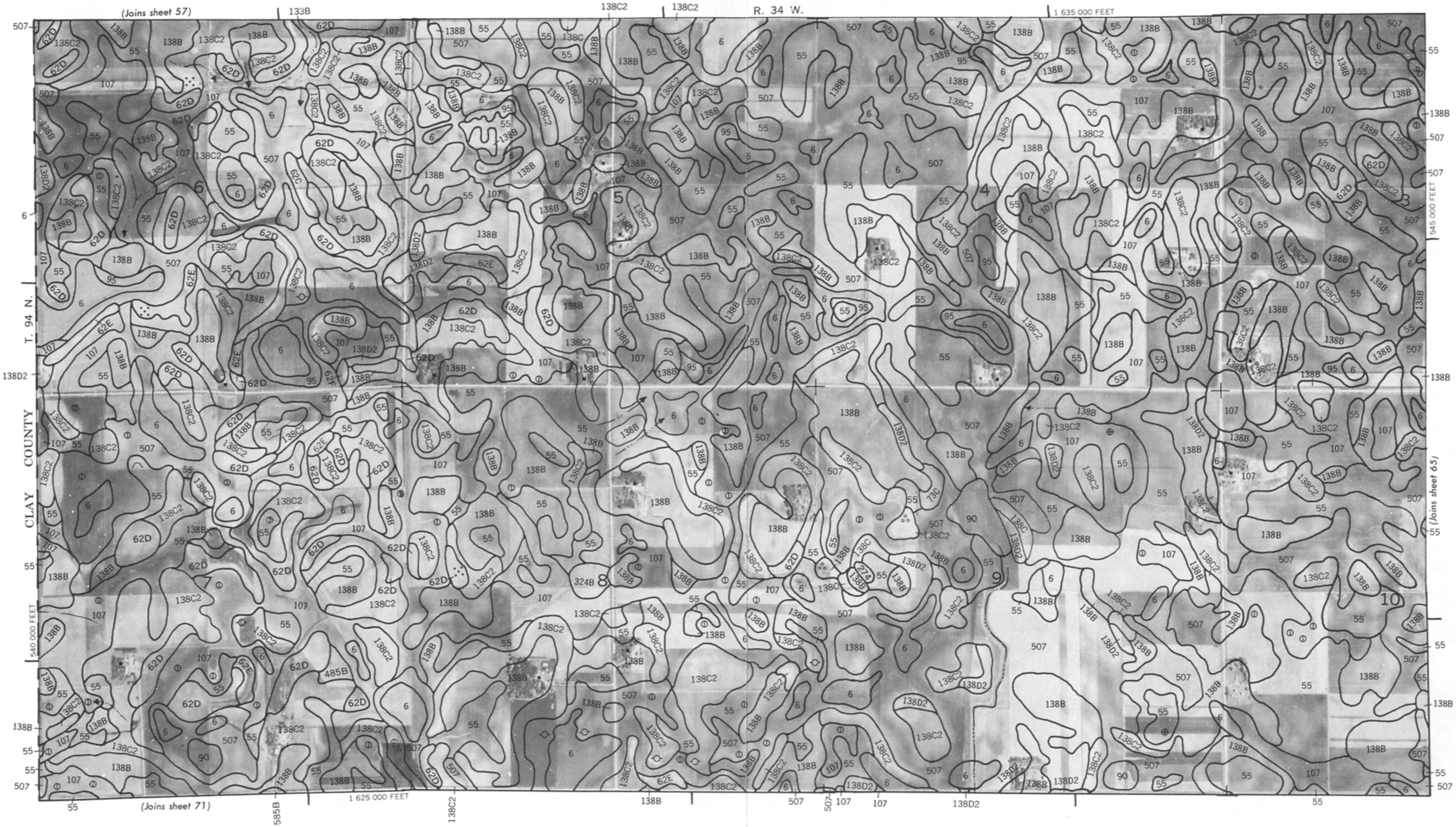
PALO ALTO COUNTY, IOWA — SHEET NUMBER 62

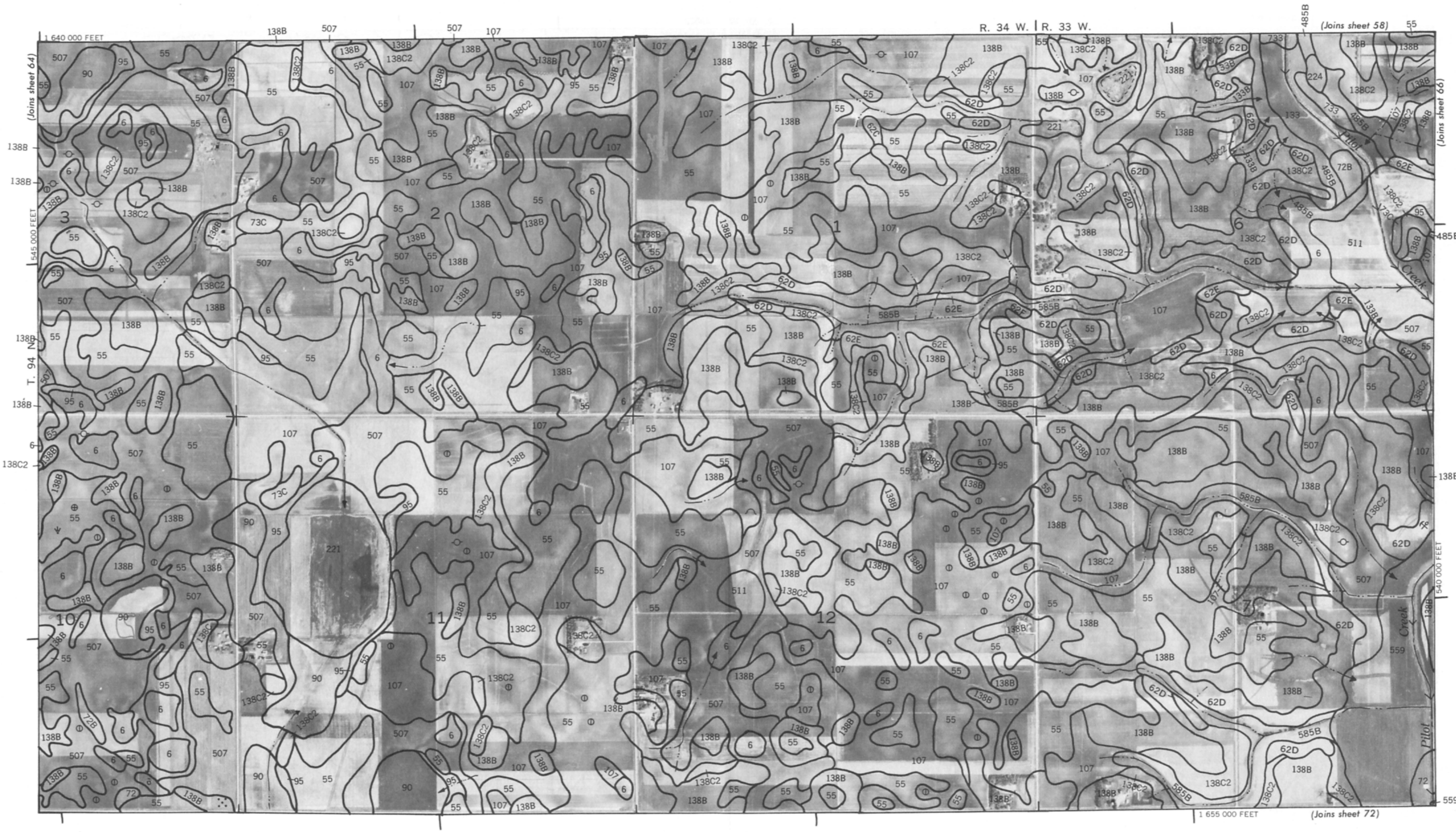
63


N
1 735 000 FEET
R. 31 W.
(Joins sheet 56)
555 000 FEET
(Joins sheet 62)
T. 94 N.
27
26
25
34
35
36
Prairie
Creek
CHICAGO
ROCK
ISLAND
AND
KOSSUTH COUNTY
15
550 000 FEET
(Joins sheet 70)
1 750 000 FEET

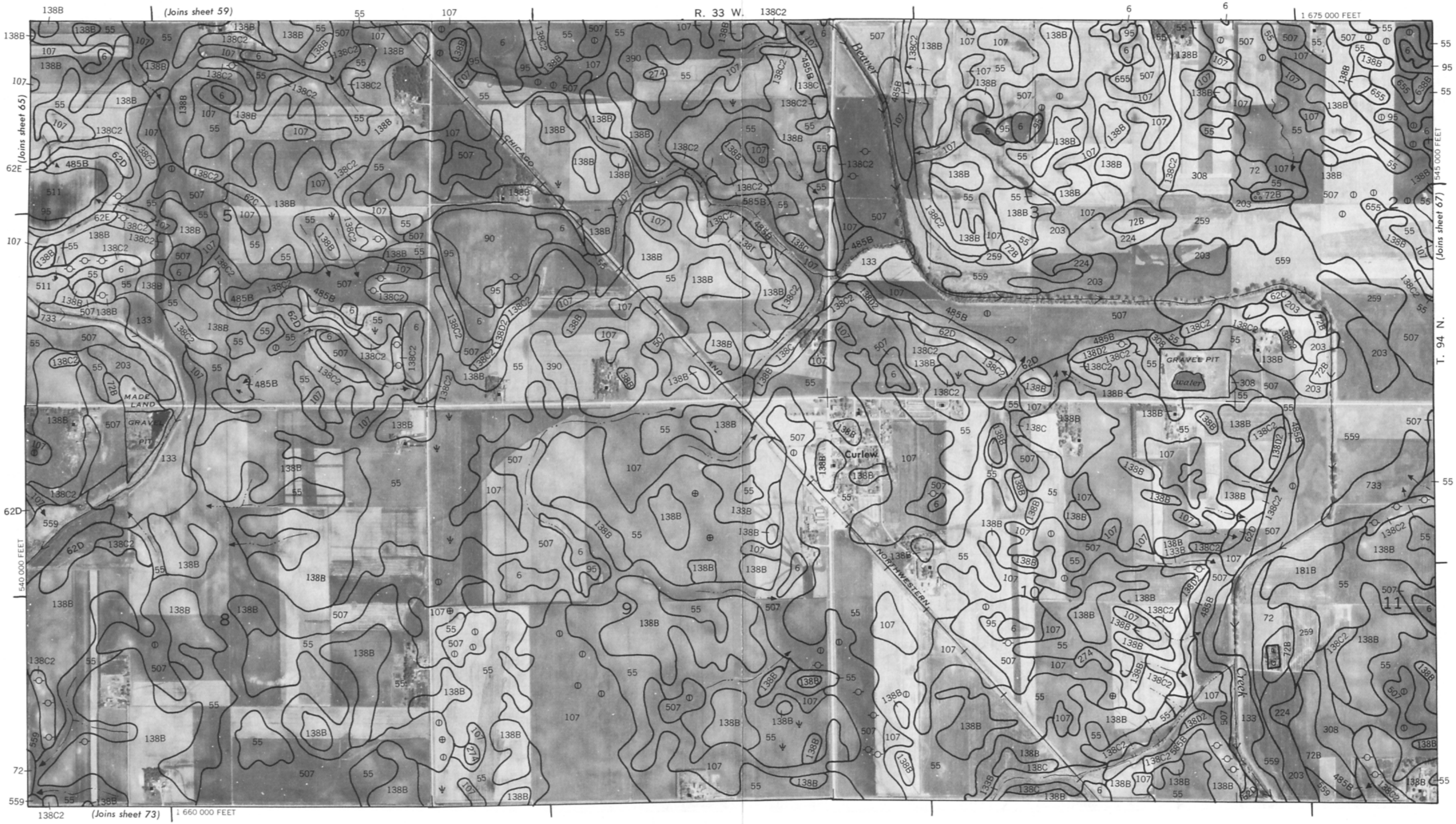
PALO ALTO COUNTY, IOWA — SHEET NUMBER 64

N



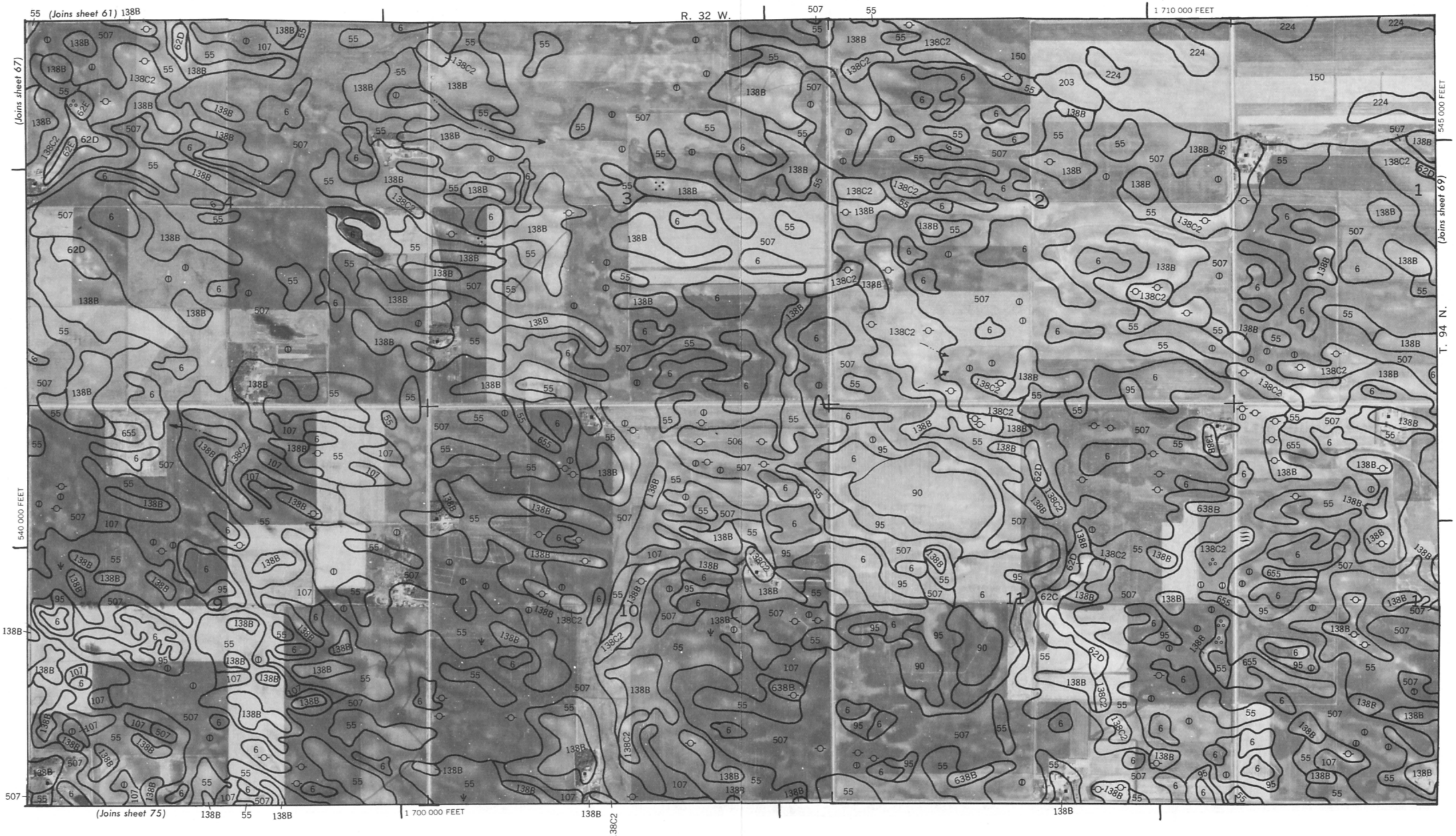

N
(Joins sheet 58)
(Joins sheet 64)
(Joins sheet 66)
(Joins sheet 72)
1 640 000 FEET
1 655 000 FEET
545 000 FEET
540 000 FEET
R. 34 W.
R. 33 W.
T. 94 N.
Pilot Creek
Creek
Pilot

N

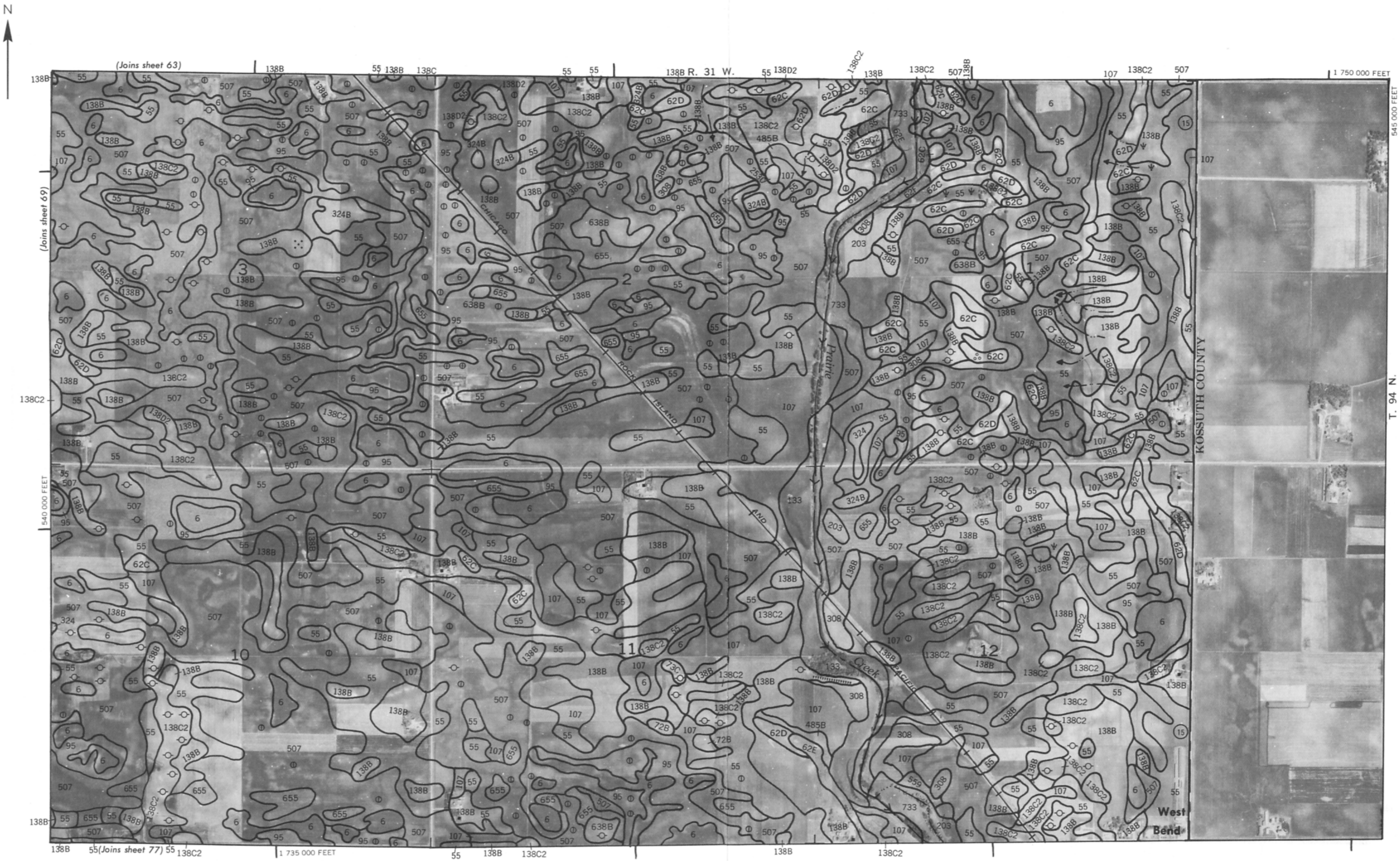

(Joins sheet 59)
R. 33 W.
1 675 000 FEET
545 000 FEET
(Joins sheet 67)
T. 94 N.
(Joins sheet 65)
540 000 FEET
(Joins sheet 73)
1 660 000 FEET
CHICAGO
AND
NORTHWESTERN
Beaver
Creek
Curlew
GRAVEL PIT
water
MADE LAND
GRAVEL PIT


N
R. 33 W.
R. 32 W.
1 680 000 FEET
(Joins sheet 60)
545 000 FEET
T. 94 N.
(Joins sheet 66)
540 000 FEET
(Joins sheet 68)
(Joins sheet 74)
1 695 000 FEET

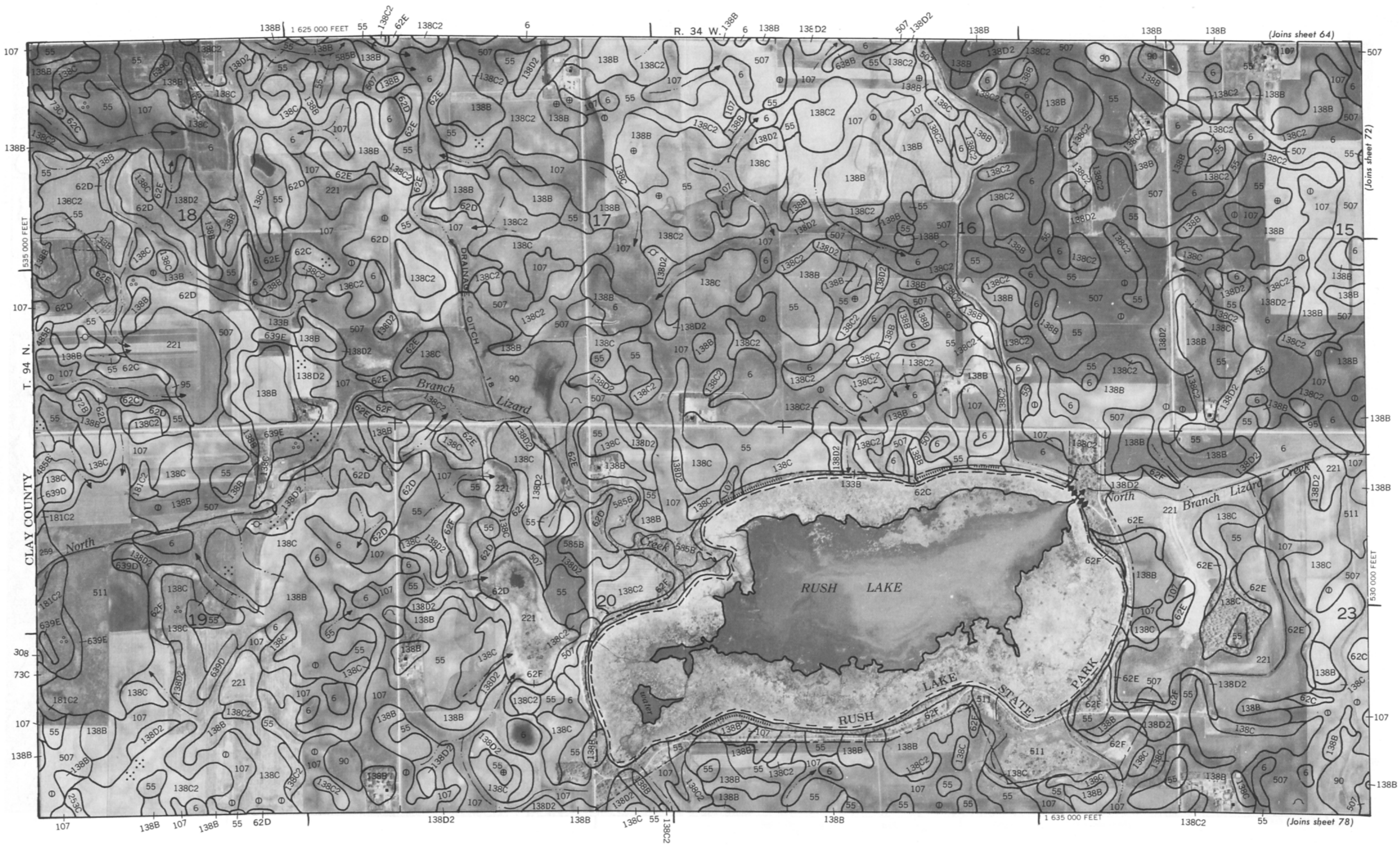
N


(Joins sheet 61)
R. 32 W.
1 710 000 FEET
(Joins sheet 67)
(Joins sheet 69)
545 000 FEET
T. 94 N.
540 000 FEET
(Joins sheet 75)
1 700 000 FEET

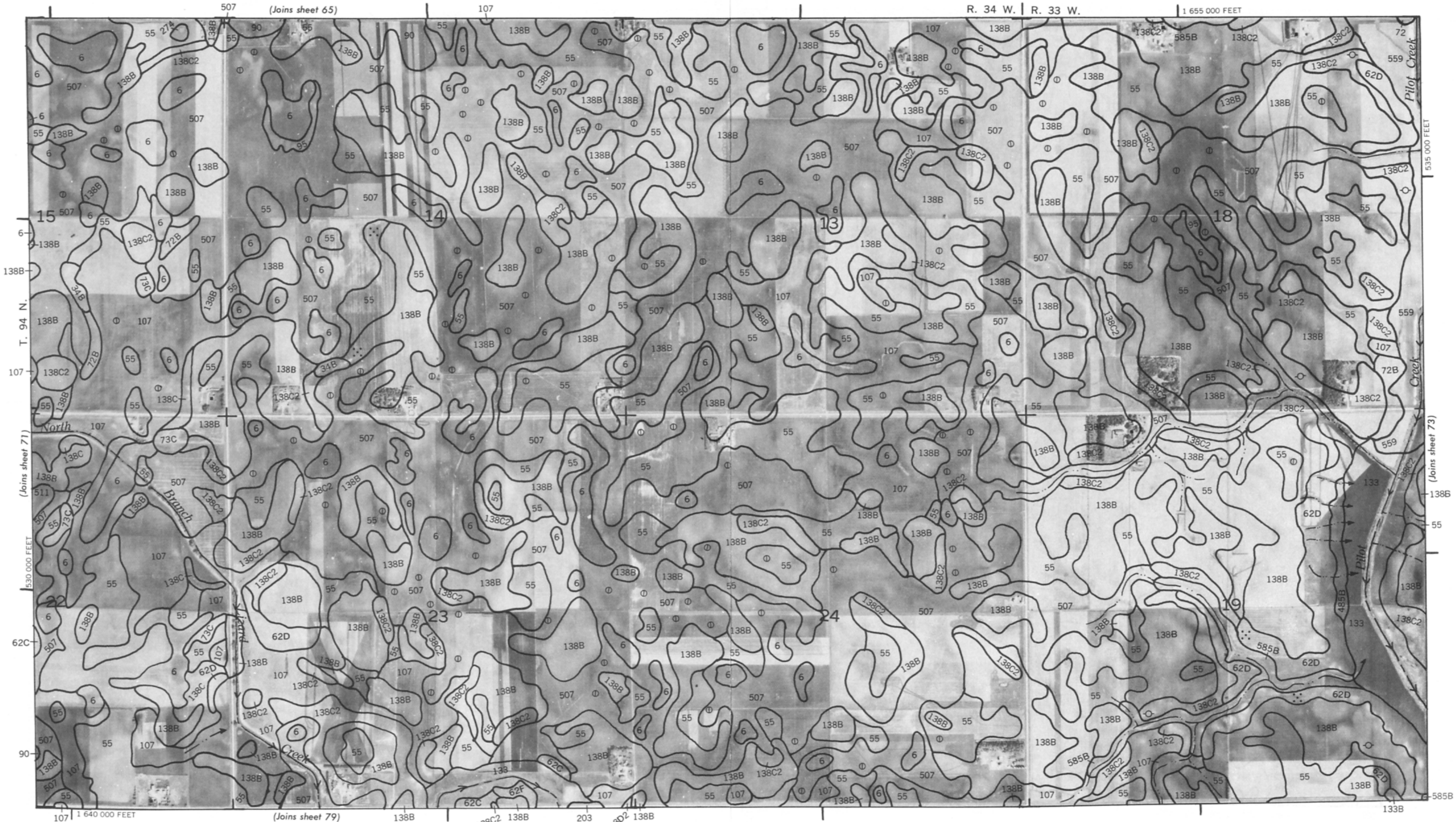

N
R. 32 W.
R. 31 W.
T. 94 N.
1 715 000 FEET
545 000 FEET
540 000 FEET
1 730 000 FEET
(Joins sheet 62)
(Joins sheet 68)
(Joins sheet 70)
(Joins sheet 76)
DRAINAGE DITCH
DES
MOINES
RIVER
Cylinder
Creek
GRAVEL PIT
water
G. P.
1
4
5
6
7
8
9
12

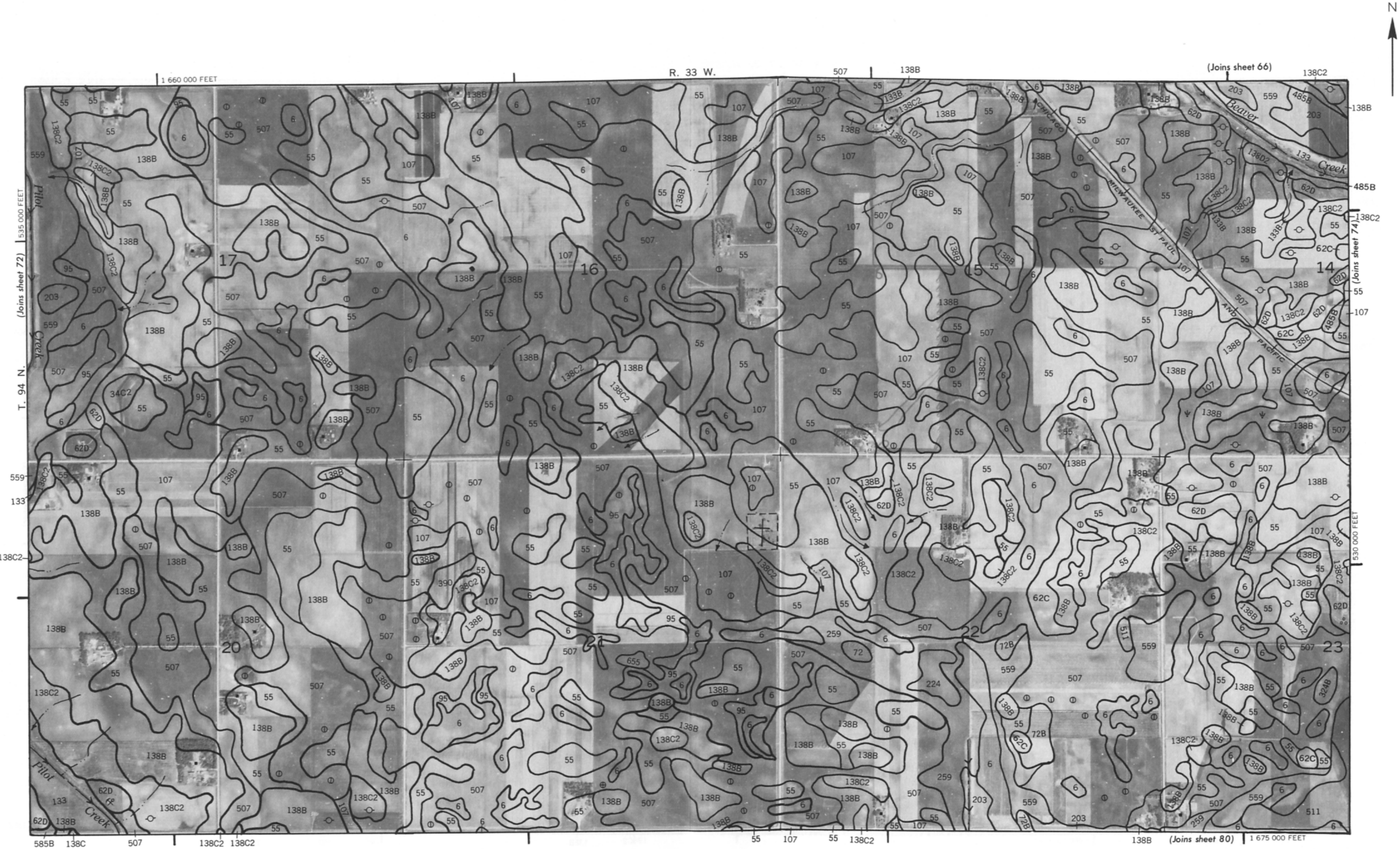

N
(Joins sheet 63)
R. 31 W.
1 750 000 FEET
545 000 FEET
(Joins sheet 69)
540 000 FEET
T. 94 N.
KOSSUTH COUNTY
CHICAGO
ROCK
ISLAND
AND
PACIFIC
Prairie
Creek
West
Bend
(Joins sheet 77)
1 735 000 FEET
15

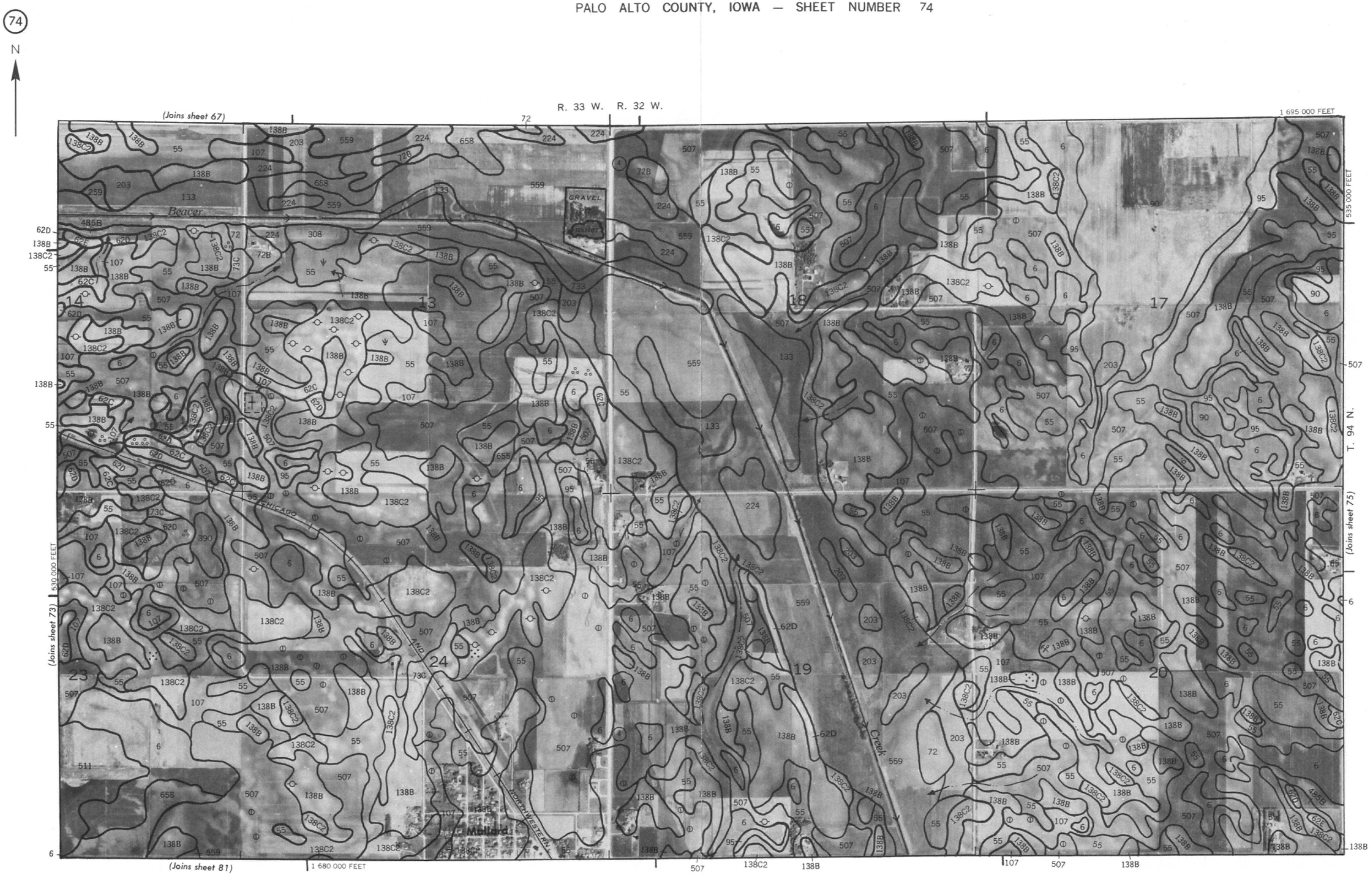
N


1 625 000 FEET
R. 34 W.
(Joins sheet 64)
(Joins sheet 72)
(Joins sheet 78)
535 000 FEET
530 000 FEET
1 635 000 FEET
T. 94 N.
CLAY COUNTY
18
17
16
15
19
20
23
DRAINAGE DITCH 18
North Branch Lizard Creek
RUSH LAKE
RUSH LAKE STATE PARK
water

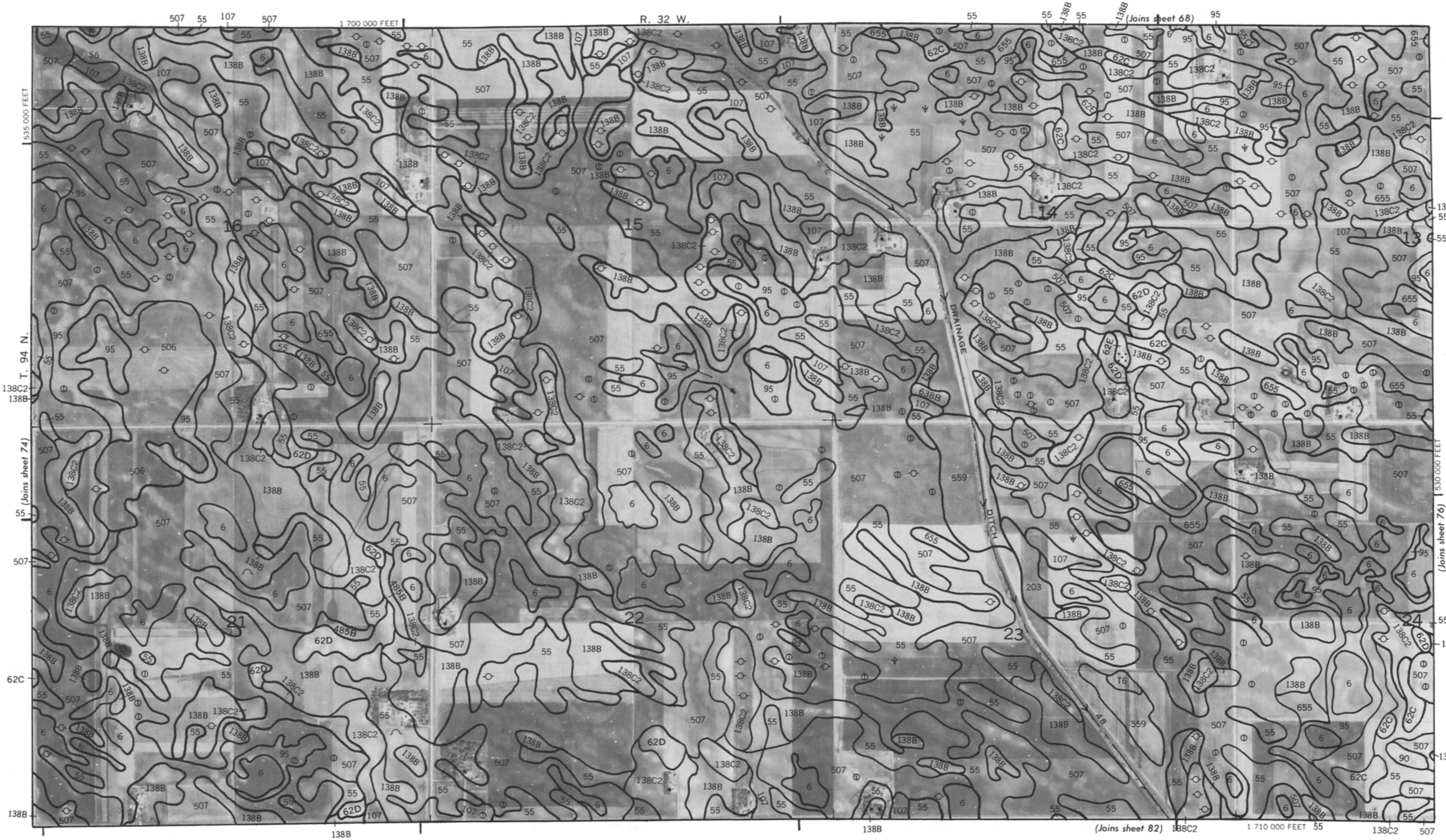
N


(Joins sheet 65)
R. 34 W.
R. 33 W.
1 655 000 FEET
535 000 FEET
T. 94 N.
(Joins sheet 71)
(Joins sheet 73)
530 000 FEET
1 640 000 FEET
(Joins sheet 79)
North
Branch
Pilot
Creek
15
14
13
18
22
23
24
19


N
R. 33 W.
T. 94 N.
1 660 000 FEET
1 675 000 FEET
535 000 FEET
530 000 FEET
(Joins sheet 66)
(Joins sheet 72)
(Joins sheet 74)
(Joins sheet 80)
Pilot Creek
Beaver Creek
CHICAGO MILWAUKEE ST PAUL AND PACIFIC
14
15
16
17
20
21
22
23

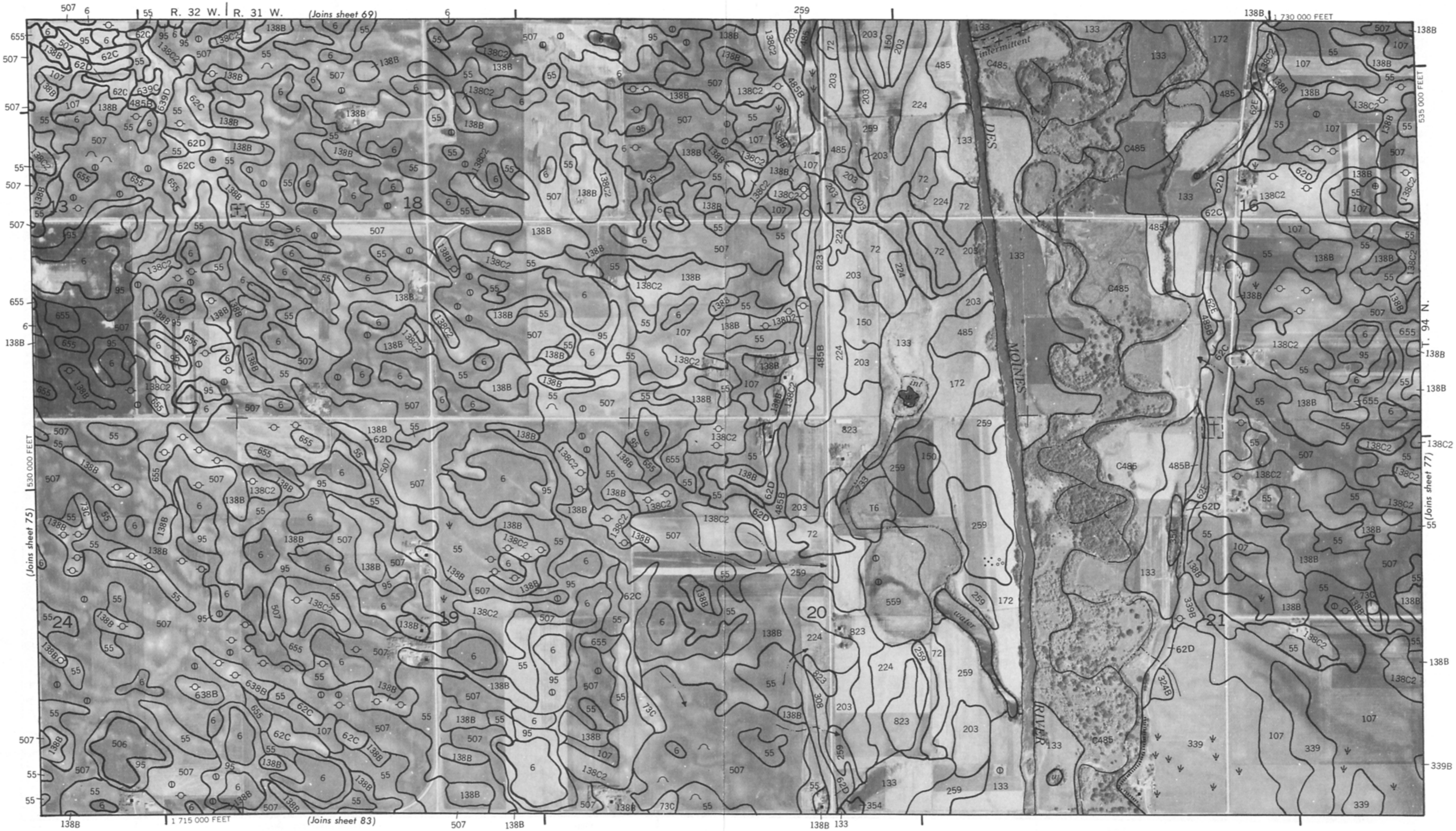

74
N
(Joins sheet 67)
R. 33 W.
R. 32 W.
1 695 000 FEET
535 000 FEET
T. 94 N.
(Joins sheet 75)
(Joins sheet 73)
530 000 FEET
(Joins sheet 81)
1 680 000 FEET
GRAVEL
Beaver
Creek
CHICAGO
AND
NORTHWESTERN
Mallard
14
13
18
17
23
24
19
20

N

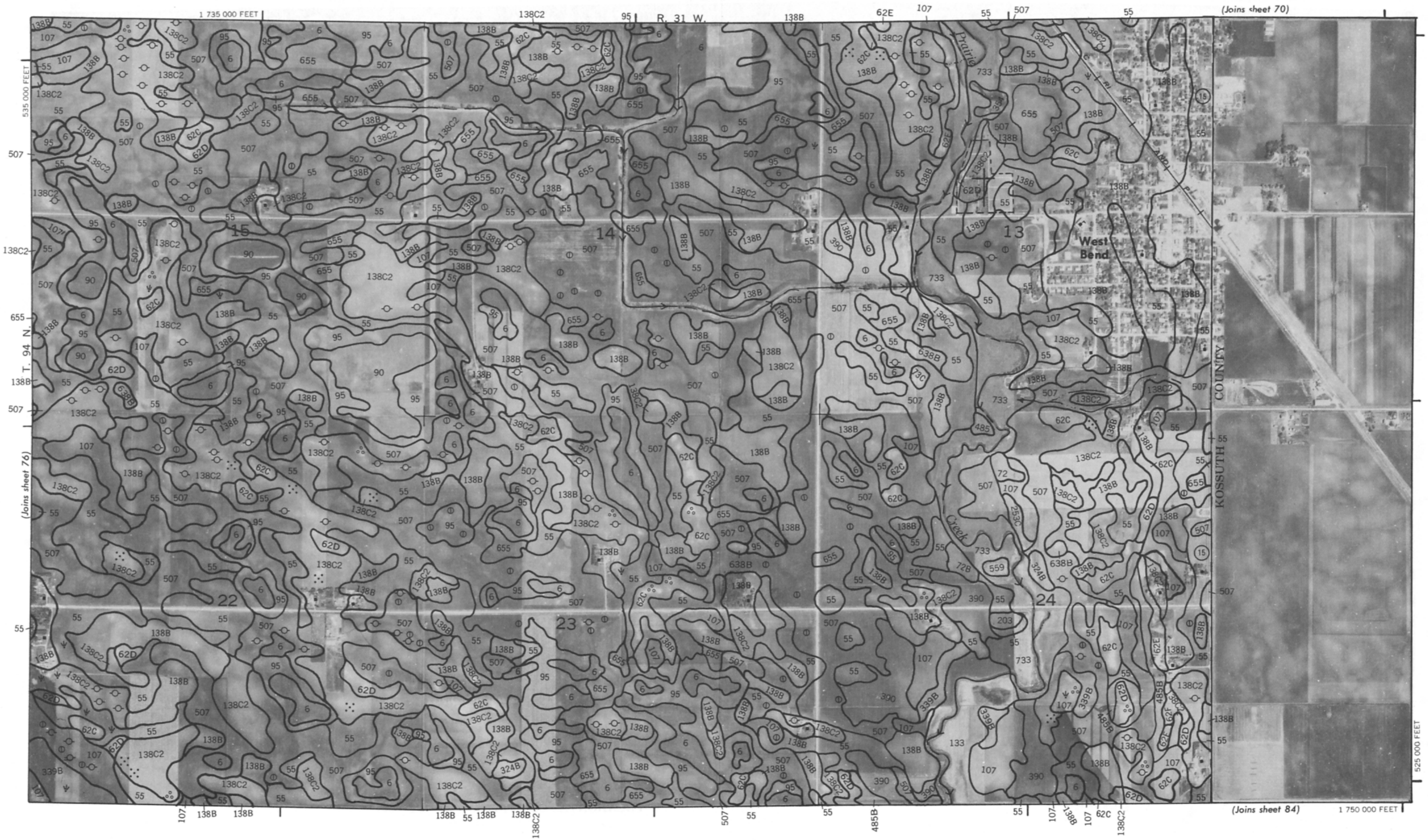

R. 32 W.
T. 94 N.
(Joins sheet 68)
(Joins sheet 74)
(Joins sheet 76)
(Joins sheet 82)
1 700 000 FEET
1 710 000 FEET
535 000 FEET
530 000 FEET
DRAINAGE DITCH
14
15
16
13
21
22
23
24

76

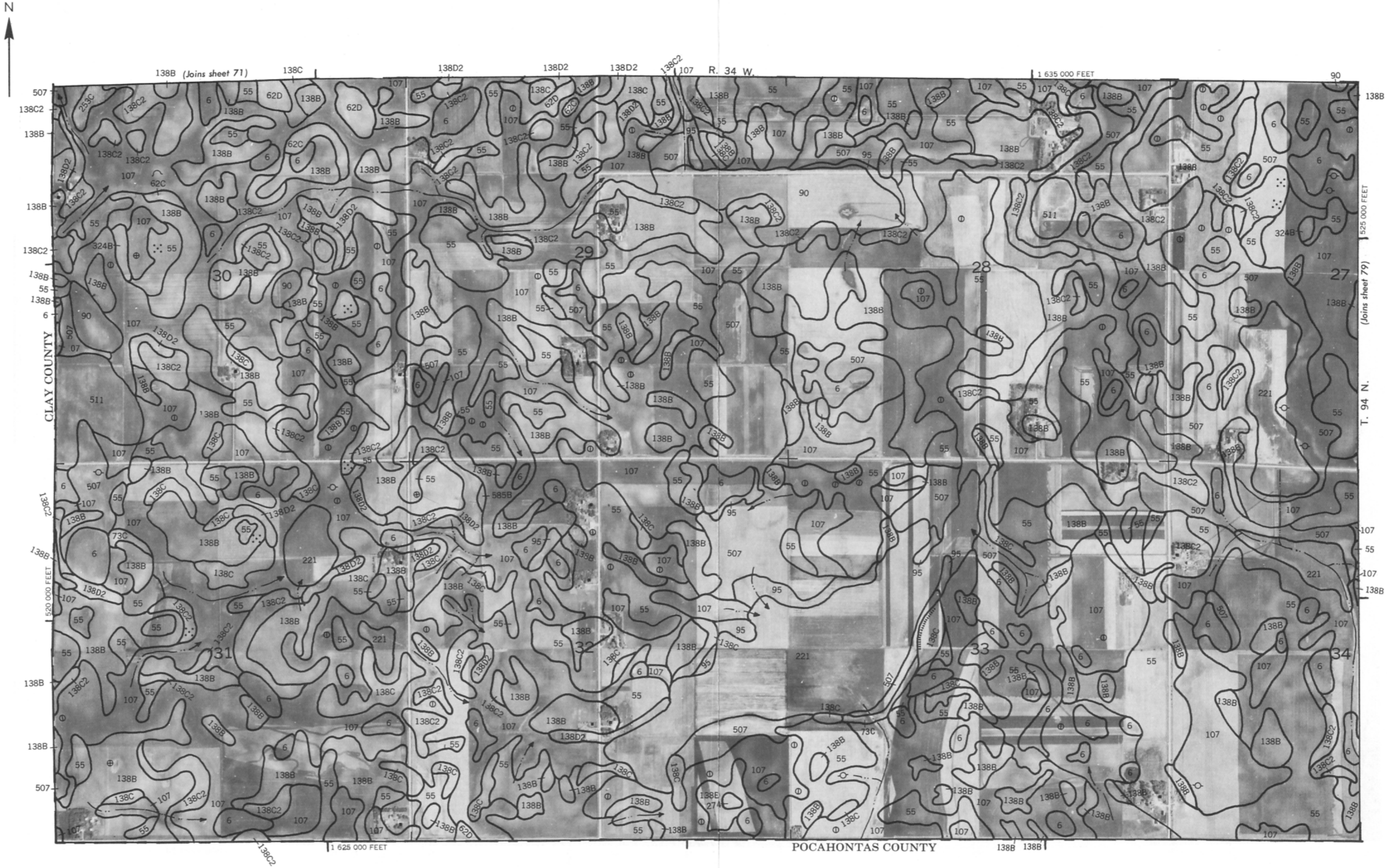
N

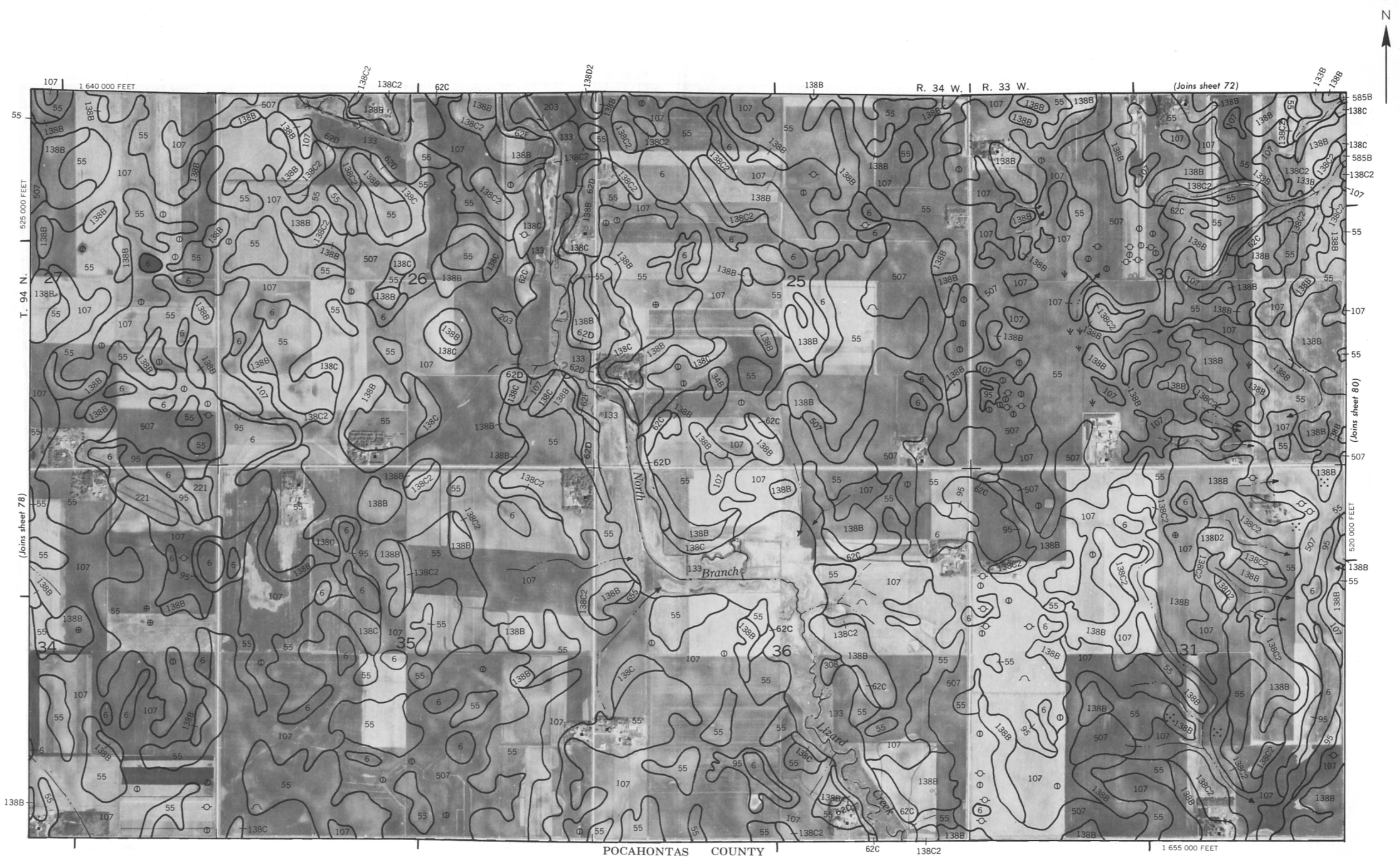

R. 32 W.
R. 31 W.
(Joins sheet 69)
(Joins sheet 75)
(Joins sheet 77)
(Joins sheet 83)
T. 94 N.
1 730 000 FEET
1 715 000 FEET
535 000 FEET
530 000 FEET
DES
MOINES
RIVER
intermittent
water
13
16
17
18
19
20
21
24

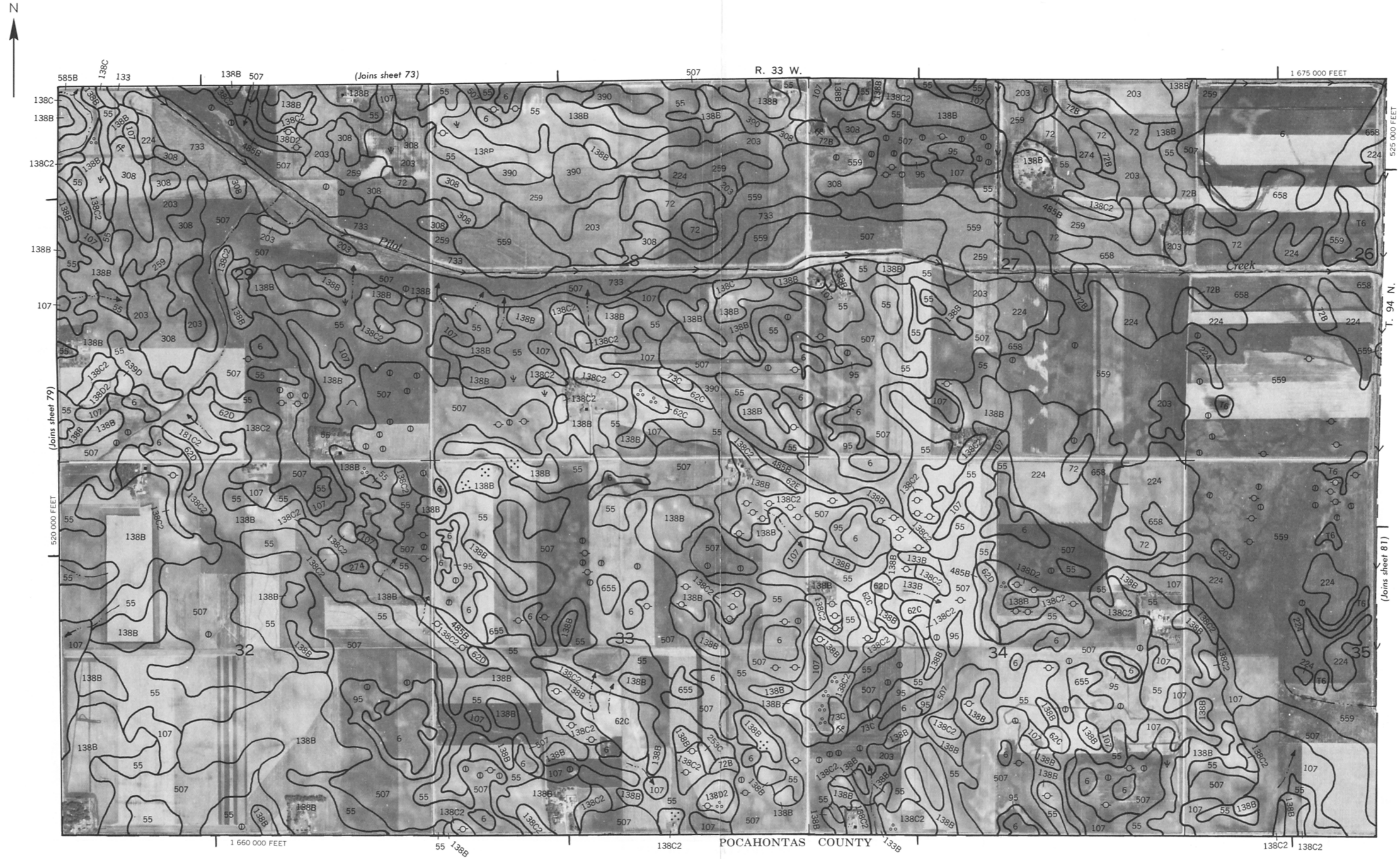
N

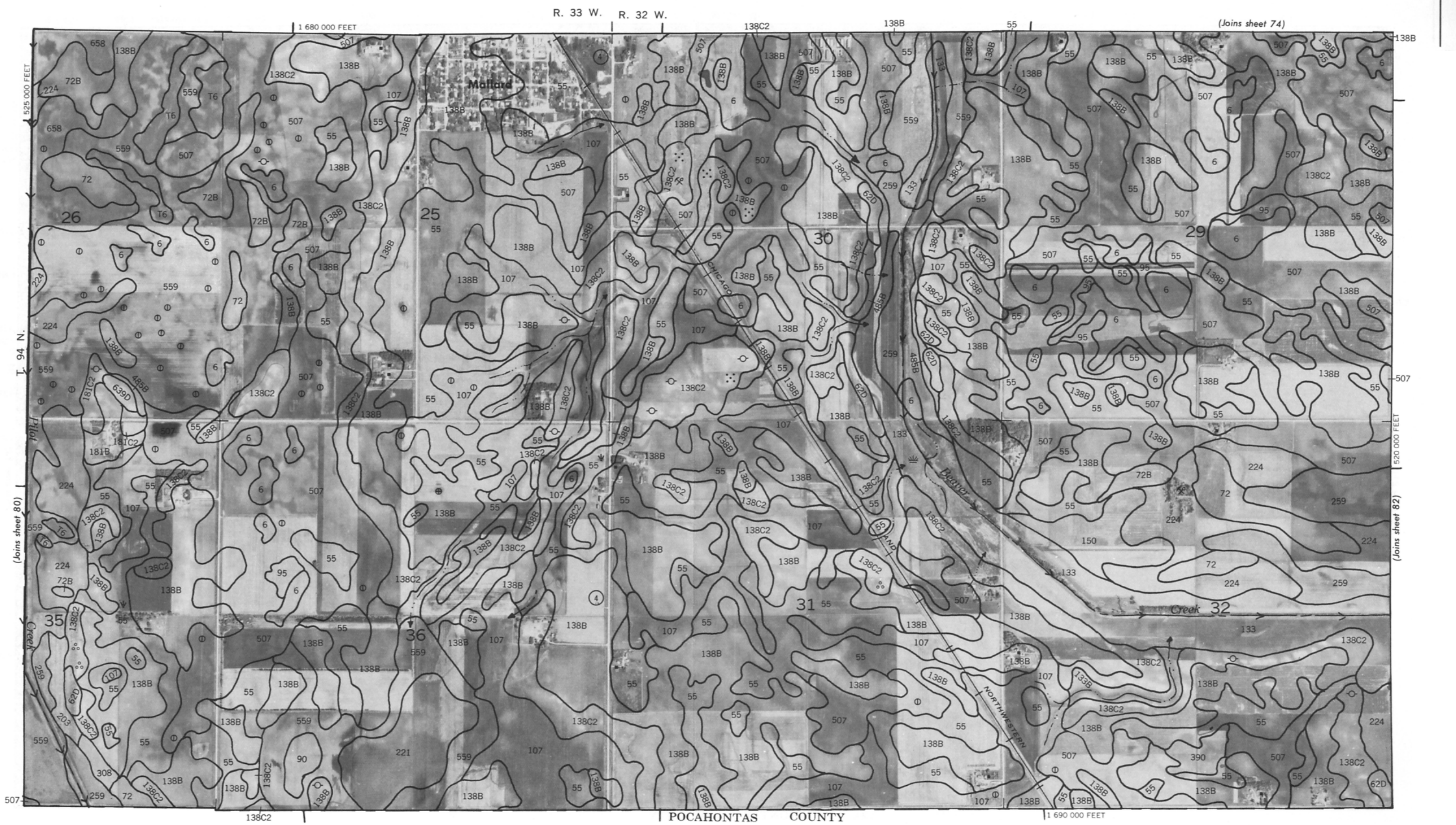

(Joins sheet 70)
(Joins sheet 76)
(Joins sheet 84)
R. 31 W.
T. 94 N.
1 735 000 FEET
1 750 000 FEET
535 000 FEET
525 000 FEET
West Bend
KOSSUTH COUNTY
Prairie Creek
15
14
13
22
23
24

78

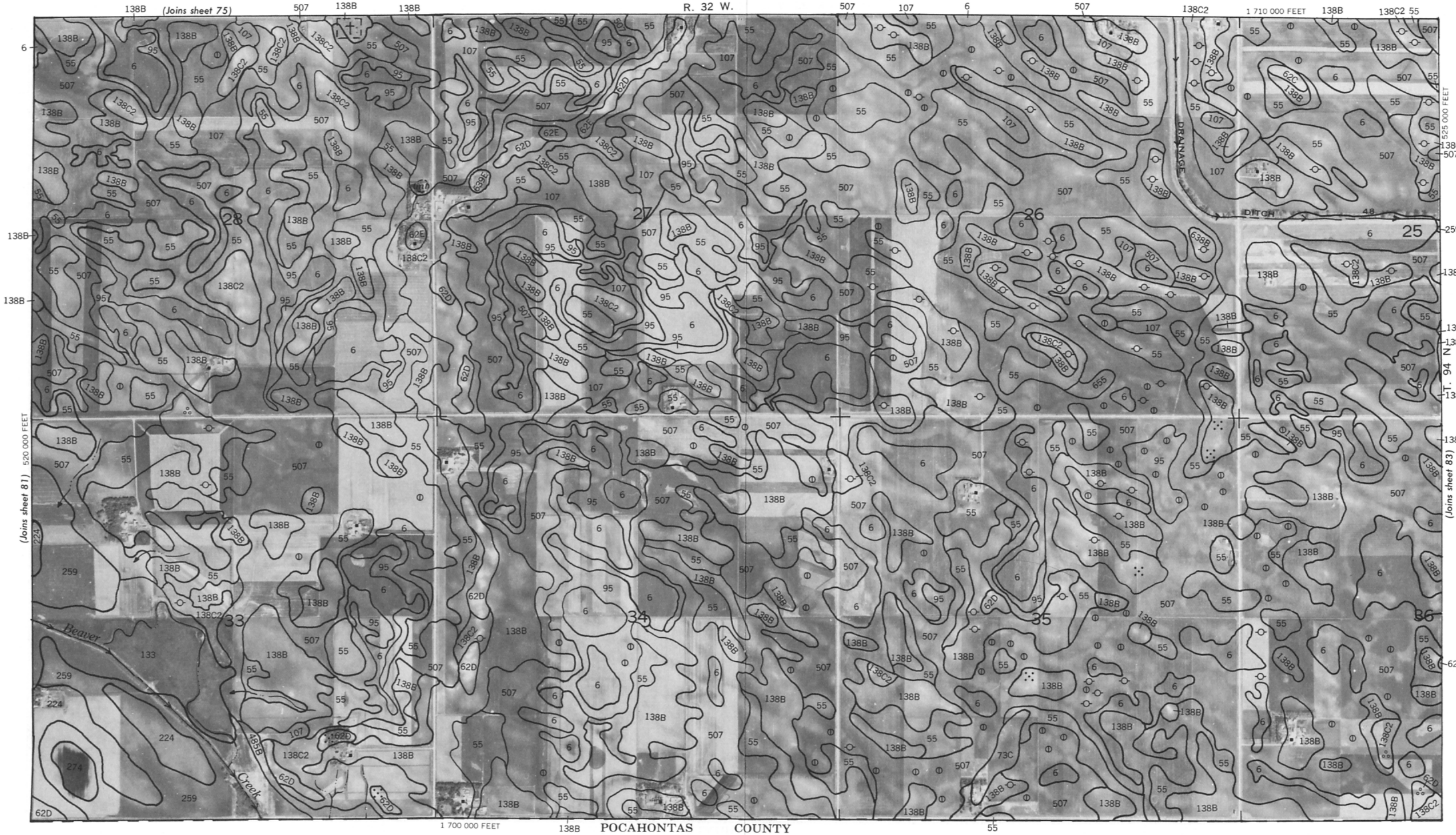

N
(Joins sheet 71)
R. 34 W.
1 635 000 FEET
525 000 FEET
(Joins sheet 79)
T. 94 N.
CLAY COUNTY
520 000 FEET
1 625 000 FEET
POCAHONTAS COUNTY
29
28
27
30
31
32
33
34

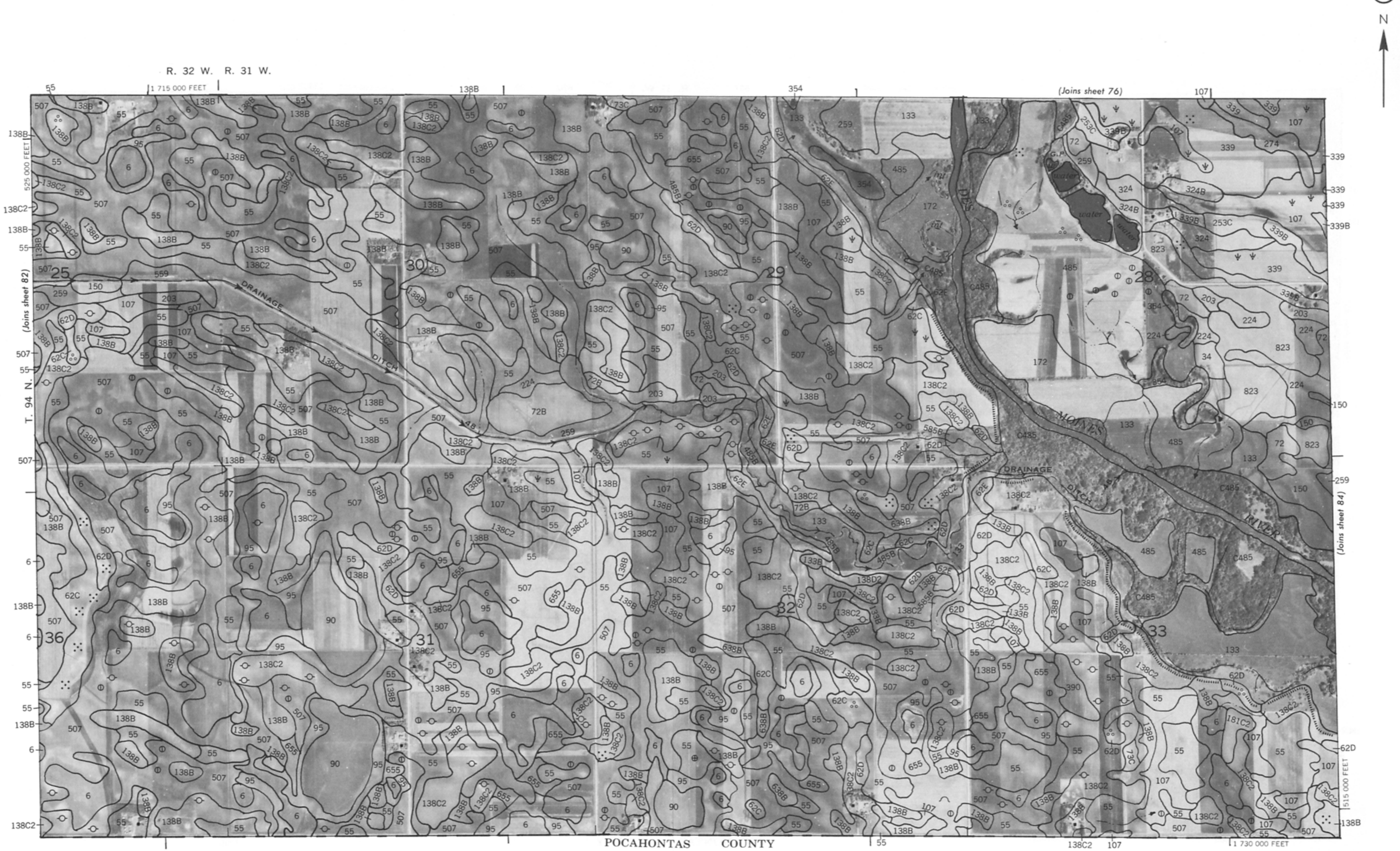

N
1 640 000 FEET
R. 34 W.
R. 33 W.
(Joins sheet 72)
(Joins sheet 80)
(Joins sheet 78)
T. 94 N.
525 000 FEET
520 000 FEET
1 655 000 FEET
POCAHONTAS COUNTY
North Branch
Lizard Creek
27
26
25
30
34
35
36
31


N
R. 33 W.
T. 94 N.
(Joins sheet 73)
(Joins sheet 79)
(Joins sheet 81)
1 675 000 FEET
525 000 FEET
520 000 FEET
1 660 000 FEET
Pilot
Creek
POCAHONTAS COUNTY
26
27
28
29
32
33
34
35


81
N
R. 33 W.
R. 32 W.
1 680 000 FEET
(Joins sheet 74)
525 000 FEET
T. 94 N.
(Joins sheet 80)
(Joins sheet 82)
520 000 FEET
1 690 000 FEET
Mallard
26
25
30
29
35
36
31
32
CHICAGO
AND
NORTHWESTERN
Beaver
Creek
Pilot
POCAHONTAS COUNTY

N


(Joins sheet 75)
R. 32 W.
1 710 000 FEET
525 000 FEET
T. 94 N.
(Joins sheet 83)
(Joins sheet 81)
520 000 FEET
1 700 000 FEET
POCAHONTAS COUNTY
DRAINAGE
DITCH
Beaver
Creek
25
26
27
28
33
34
35
36


83
N
R. 32 W. R. 31 W.
1 715 000 FEET
(Joins sheet 76)
(Joins sheet 82)
(Joins sheet 84)
T. 94 N.
525 000 FEET
515 000 FEET
1 730 000 FEET
DRAINAGE DITCH
DES MOINES RIVER
POCAHONTAS COUNTY


N
(Joins sheet 77)
R. 31 W.
1 745 000 FEET
(Joins sheet 83)
KOSSUTH COUNTY
T. 94 N.
520 000 FEET
515 000 FEET
1 735 000 FEET
POCAHONTAS COUNTY
WEST FORK DES MOINES RIVER
Prairie Creek
27
26
25
34
35
36